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EDGEWOOD ARSENAL TECHNICAL REPORT

EATR 4309

TOXICOLOGY OF RIOT CONTROL CHEMICALS – CS, CN, and DM

by

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November 1969

Project 1B562602A079

DEPARTMENT OF THE ARMY
EDGEWOOD ARSENAL
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FOREWORD

The work described in this report was authorized under Project 1B562602A079, Non-Defense Medical Aspects of Chemical Agents (U). The work is a compilation of experimental data from 1918 through 1968.

In conducting the research described in this report, the investigators adhered to the "Guide for Laboratory Animal Facilities and Care" as promulgated by the Committee on the Guide for Laboratory Animal Resources, National Academy of Sciences–National Research Council.

The volunteers in these tests are enlisted US Army personnel. These tests are governed by the principles, policies, and rules for medical volunteers as established in AR 70-25.

DIGEST

This report summarizes information on the physiological and toxicological effects of three riot control agents: CS, *o*-chlorobenzalmalononitrile; CN, chloroacetophenone; and DM, dimethyl aminochloroarsine. Included in the report is a review of the toxicity tests conducted on the old compounds CN and DM by various organizations from 1918 to the present, and on CS from 1958 to the present. Detailed results of experiments conducted by the Toxicology Department, Medical Research Laboratory, by various methods on animals of several species are given. Based on the animal experiments, estimates are given for lethal doses in man. Incapacitating doses are determined and reported on the basis of tolerance times of volunteers exposed to aerosols of the three compounds. Safety factors, derived from ratios of estimated lethal doses to incapacitating doses, are reported for the three compounds.

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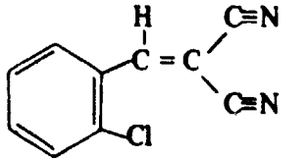
TOXICOLOGY OF RIOT CONTROL CHEMICALS -- CS, CN, AND DM

I. RESUME.

A. Introduction.

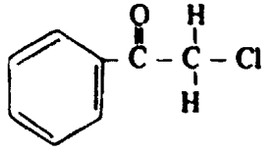
CS, CN, and DM are crystalline, solid compounds which are classified as irritants. They are soluble in organic solvents but poorly soluble in water. Their structural formulae are as follows:

CS



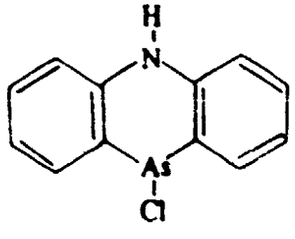
o-chlorobenzalmalononitrile
o-chlorobenzylidene malononitrile

CN



o-chloroacetophenone

DM



Diphenylaminochloroarsine
10-chloro-5,10-dihydrophenarsazine, adamsite

These substances can be disseminated as dry powders by thermal or explosive methods or by spraying the molten materials or solutions of the materials.

All three substances act directly on the mucous membranes to produce irritation and burning and pain in the eyes, nose, throat, and respiratory tract. The action on the eyes also causes lacrimation, blepharospasm, and conjunctivitis. The effects on the respiratory passages and lungs cause sneezing, coughing, salivation congestion of the nose and walls of the pharynx, and a feeling of suffocation. These effects are noted immediately and they persist 5 to 30 minutes after exposure is terminated.

Sensitization to the cutaneous effects may occur in some persons as a result of exposures to these irritants. Prolonged or repeated exposure to high concentrations of these irritants can cause erythema and vesiculation in sensitive persons. Elevated environmental temperature, high relative humidity, and friction of agent with the skin may be contributory factors to skin damage.

Prolonged exposure to very high concentrations of these irritants can cause death by damage to the respiratory tract and lungs. In general, the margin of safety between the irritant doses and the lethal doses is very great.

There are certain qualitative differences among the three irritants. In general, CS has the most desirable combination of irritant potency, fast action, and low toxicity. In addition to the irritant action, DM produces systemic effects, including headache, perspiration, chills, nausea, vomiting, intestinal cramps, and a feeling of depression and malaise. These effects start about 30 minutes after the beginning of the exposure and they persist for several hours after termination of exposure.

B. Dose Estimate for Man.

1. General Considerations.

a. Source of Information.

When men are likely to be exposed to chemical agents, it is important to obtain information on effective doses, toxic doses, and lethal doses. Sometimes the information must be derived solely by experimentation in animals. Occasionally, combined information from tests on animals and men are used to estimate the probable doses for man. For some agents, it is possible to obtain all of the necessary information solely from experimentation in man. In the present paper the irritant doses were determined primarily in man. The systemic dose of DM was estimated from experimentation in animals and man. The lethal doses for man were estimated from data obtained in various species of animals. Usually the lethal doses were calculated by combining the data for all of the species to obtain an estimated dose for lower mammals. Man was then considered as another mammal.

b. LCt50 and ICt50.

CT is a measure of airborne dosage. It is the product of the concentration (C) in mg/cu m multiplied by the exposure time (t) in minutes. The term has been long and widely

used. It is especially applicable to conditions in which an inhaled and retained quantity of material accumulates within the body until the dose is sufficient to produce a biological effect such as death or vomiting. The term LCt50 and ICt50 mean airborne doses which are lethal (L) or incapacitating (I) in 50 percent of a population exposed to a given dose (Ct). The term ICt50 has a somewhat special connotation when related to irritants; the higher the concentration the shorter the exposure time men will tolerate. Usually the ICt50 means the concentration in mg/cu m which will be intolerable to 50 percent of an exposed population in 1 minute. To describe the effectiveness of irritants, a combination of concentration, tolerance time, and percent of population responding is required. Single ICt50's are still used widely for irritant and other compounds for purposes of comparison among agents

In the determination of ICt50's for irritants, a man is considered incapacitated when he will no longer remain in the contaminated atmosphere. When men can be motivated to remain in the cloud of certain irritants for 3 minutes or more, a condition of adaptation ensues and the irritant effects diminish. Adaptation has been noted at concentrations of 6 mg/cu m or less for CS.* The possibility exists that adaptation may occur at higher concentrations if men could be motivated to endure the irritancy. The decision to tolerate the irritant is strongly influenced by the individual's will to resist. The factors of motivation and adaptation have resulted in marked differences in ICt50 values for a given compound in various experiments.* At present there is a tendency to express the ICt50 of irritants as those ranges of concentrations (mg/cu m) which will be intolerable to 50 percent of a population. Future studies must relate ICt50 to the population's degree of motivation to resist the agents and to the level of adaptation which can be attained.

2. Irritant ICt50 Values for CS, CN, and DM.

The ranges of concentrations which will be intolerable in 1 minute to 50 percent of a population in laboratory testing situations for CS, CN, and DM are as follows:**

CS: 0.1 – 10.0 mg/cu m
CN: 20 – 213 mg/cu m
DM: 22 – 220 mg/cu m

The exact concentration depends upon the population's degree of motivation to resist.

3. ICt50 for DM (Systemic).

At Ct levels ranging from 3.75 to 236 mg min/cu m studied by various investigators in 101 men,† it was indicated that the ICt50 for systemic effects had not been reached. Additional exposures beyond a Ct of 200 mg min/cu m were deemed inadvisable and it was necessary to supplement the human data with animal data to obtain ICt50 values for systemic activity.

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*Unpublished data, Aerosol Branch, Toxicology Department.
**Unpublished data, Human Estimates Committee, Research Labs.
†Unpublished data, Aerosol Branch, Toxicology Dept.

Based on the human and animal studies, an ICt50 of 370 mg/cu m was established as the Research Laboratories' human estimate for the dose of inhaled DM which would produce nausea and vomiting in 50 percent of a population.

4. LCt50's of CS, CN, and DM.

a. General.

Inhalation toxicity tests of various types of aerosol dispersions (agent melted and sprayed in the molten form, dispersed as a dry powder, sprayed from solutions in acetone or methylene dichloride which are nontoxic solvents, dispersed from grenades by liberation of hot gases) have been performed since World War I. Prior to the research on CS in 1958 and 1959, no toxicity studies were performed using munitions. All CN and DM munition studies were done in 1965. In these studies, it has been a generally consistent finding that the munition-dispersed agents are less toxic than those dispersed by some of the other methods. Because of this finding, separate estimates for munitions have been prepared (table I).

The LCt50 values for individual and combined animal species are given in table II. Detailed toxicity data are shown in the appendix, tables A-I to A-V and A-XI to A-XIX. The official human estimates for LCt50's are based on toxicity data for the combined animal species.

b. Official Human Estimates.

(1) CS.

The Research Laboratories, Edgewood Arsenal, Maryland, official estimates for inhalation LCt50's of CS in man are:

Molten dispersion	– 52,000 mg min/cu m
M7A3 grenade	– 61,000 mg min/cu m

(2) CN.

The Research Laboratories official estimates for the inhalation LCt50's of CN are:

Laboratory-type dispersion	7,000 mg min/cu m
Commercial grenade	14,000 mg min/cu m

(3) DM.

The Research Laboratories official estimates for the inhalation LCt50's of DM are:

Laboratory-type dispersion	11,000 mg min/cu m
M6A1	44,000 mg min/cu m
Commercial grenade	35,000 mg min/cu m

Table 1. Estimated ICt50's, LCt50's, and Safety Factors for Riot Control Chemical Agents for Man

Agent	Dispersion System	ICt50 mg min/cu m	LCt50 mg min/cu m	Safety Factor ICt50/LCt50
CS	Molten	0.1-10.0	52,000[a,3]	5200-520,000
	M7A3[b]		61,000[a,3]	6100-610,000
CN	Laboratory dispersion	20-213	7,000[a,3]	33-350
	Commercial grenade		14,000[a,3]	65-700
DM				
(Irritant)	Laboratory dispersion	22-220	11,000[a,4]	50-500
	M6A1[b]		44,000[a,4]	200-2000
	Commercial grenade		35,000[a,4]	160-1600
(Systemic)	Acetone dispersion	370[a,1]	11,000-44,000 (see above)	30-119

[a]Research Laboratories official values.
[b]Standard Army riot control munition.

Table II. Lethal Doses of Irritants in Animals

Irritant	CS											
Type of Dispersion	Molten		M7A3		In Methylene Dichloride		CS2[a]		In Acetone		M18 Grenade	
Date	1958-1959		1965		1959		1967		1958-1959		1959	
Animal Species	No. of Animals	LCt50	No. of Animals	LCt50	No. of Animals	LCt50	No. of Animals	LCt50	No. of Animals	LCt50	No. of Animals	LCt50
1. Mouse	120	41,790			66	626,571						
2. Rat	70	32,293	160	94,378	160	1,004,427	120	67,588			79	163,832
3. Guinea pig	70	8,410	220	65,573	120	45,838	100	49,082	50	>35,000	80	36,439
4. Rabbit	20	17,452	66	37,683	32	>47,000						
5. Dog	36	33,551	42	29,748			30	70,400				
6. Monkey	31	50,089	30	123,195			30	74,127				
7. Swine	4	> 86,000	35	16,949								
8. Goat	16	>104,000	35	48,171								
9. Burro	4	> 61,000										
10. Sheep	4	ca. 64,000										
11. Sick goat[b]	16	>104,000										
12. Sick monkey[b]												
13. Pigeons	24	32,121			18	>30,000						
14. Chickens	16	> 49,000			24	644,207						
Combined Species	1-6[c] 2,3,5,6[c]	52,099[c] 75,218	2-8[c]	60,674[c]	1-4[c]	1,230,497[c]	2,3,5,6[c]	60,710[c]	3[c]	>35,000	2,3[c]	78,778[c]

Table II. Continued

Irritant	CN				DM					
Type of Dispersion	Laboratory		Commercial Grenade		Laboratory		M6A1		Commercial Grenade	
Date	1918-1965		1965		1918-1965		1965		1965	
Animal Species	No. of Animals	LCt50	No. of Animals	LCt50	No. of Animals	LCt50	No. of Animals	LCt50	No. of Animals	LCt50
1. Mouse	288	slope reverse			114	46,245				
2. Rat	330	8,207	120	23,332	530	12,710	180	66,856	220	48,217
3. Guinea pig	256	8,525	120	15,399	342	6,599	120	12,591	220	29,888
4. Rabbit	48	5,842	36	15,773	36	2,903	36	41,159	156	46,959
5. Dog	92	7,035	30	16,515	106	13,945	36	28,193	30	28,428
6. Monkey	30	17,542	30	11,115	46	13,886	36	19,569	30	22,814
7. Swine	30	4,384	48	5,483	30	56,361	30	36,011	30	35,888
8. Goat	30	2,463	36	15,157	29	12,072	36	8,076	36	11,723
9. Burro										
10. Sheep										
11. Sick goat										
12. Sick monkey										
13. Pigeons										
14. Chickens										
Combined Species	1-8[c]	6,539[e]	2-8[c]	14,204[e]	1-8[c]	11,309[e]	2-8[c]	43,808[e]	2-8[c]	34,683[e]

[a]Dry CS2 containing 5% Cab-O-Sil and 0.25% hexamethyldisilazane.

[b]See explanation, p

[c]Species included in LCt50 estimate.

[e]Values were rounded out for use as RL official human estimates of LCt50's.

C. Effects and Cause of Death Associated with Lethal Inhalation Exposure to CS, CN, and DM.

One of 22 men died after being exposed to DM while asleep in an Army barracks. The victim was trapped inside and his exposure lasted 5 to 30 minutes according to different reports.

Four deaths associated with CN are described in the medical literature. All four resulted from police action against individuals who were in enclosed spaces.

CS has not been imputed as a cause of death in man.

A considerable amount of data is available on deaths in animals following exposures to CS, CN, or DM. All of the data on deaths associated with CN and DM reveal that the most prominent signs and symptoms (rales, rhonchi, dyspnea, chest pain, shortness of breath) and the pathological signs (edema, congestion, hemorrhage of lungs, pseudomembrane formation, pneumonia, etc.) are related to damage to air passages and lungs.

CN as an aerosol, in very high doses, may be more damaging to the eyes and skin than DM or CS.

D. Toxicity of Intragastrically Administered or Ingested CS.

The LD50 values (with 95 percent confidence limits) for CS administered by stomach tube to rats and rabbits are 822 (599 to 1127) mg/kg and 401 (354 to 453) mg/kg, respectively. Corresponding values for CS2 are 985 (811 to 1196) mg/kg and 379 (251 to 571) mg/kg, respectively.

When uncontaminated food was not available, rats and rabbits ate food that had been contaminated with CS and consumed average daily doses of more than 200 mg/kg of CS. Most of these animals gained weight and showed no signs of toxic effects.

II. TOXICOLOGY OF CS.

A. Toxicity Studies of CS in Animals (General).

1. Animals Used.

Toxicity determinations were conducted in healthy mice, rats, guinea pigs, rabbits, dogs, monkeys, goats, swine, sheep, burros, pigeons, and chickens.[2] In addition, goats and monkeys suffering from respiratory diseases were included in the toxicity studies. The goats were rendered pneumonic by injecting 50 mg/kg of cortisone to lower their resistance to infection and 24 hours later introducing *Pastuerella multocida* or bovine kidney tissue into the trachea. The sick monkeys were suffering from chronic pulmonary tularemia.

2. Dissemination of CS Aerosols.

In the toxicity studies[2] the CS was disseminated as an aerosol by various methods:

a. Spraying the molten agent
b. Spraying a 10 percent solution of CS in methylene dichloride
c. Spraying of 5 percent solution of CS in acetone
d. Dispersion from the M18 thermal grenade
e. Dispersion from the M7A3 thermal grenade
f. Dispersion of dry, powdered, CS-containing antiagglomerants

3. Animal Exposure Times and Observation Periods.

The exposure times ranged from 5 to 90 minutes and the observation periods were at least 14 days in all species.[2]

4. Toxicological Signs in Animals.[2]

Immediately upon exposure to CS the mouse, rat, guinea pig, rabbit, dog, and monkey became hyperactive. Copious lacrimation and salivation occurred within 30 seconds in all of the above species except the rabbit. After 5 to 15 minutes the excitement was supplanted by lethargy and dyspnea. This continued for about 1 hour after exposure. All other signs subsided within 5 minutes after the animals were removed from the contaminated atmosphere. The goat, pig, sheep, and burro showed few signs of excitement in the presence of the agent. In a given species the toxicological signs were similar for all dispersion methods.

B. Toxic Doses of CS Following a Single Exposure.

1. Toxic Doses of CS Dispersed from Methylene Dichloride.

LCt50 values in mice, rats, and guinea pigs for CS dispersed from methylene dichloride solution were 627,000, 1,004,000 and 46,000 mg min/cu m, respectively. No deaths occurred in rabbits which were exposed in groups of four to Ct's of 10,000, 10,000, 10,000, 12,000, 13,000, 15,000, 33 000, and 47,000 mg min/cu m.

The combined LCt50 for CS dispersed from methylene dichloride for mice, rats, guinea pigs, and rabbits was 1,230,000 mg min/cu m.

The LCt50 for pigeons was 644,000 mg min/cu m.

CS at Ct's up to 30,000 mg min/cu m did not kill any of 18 monkeys with pulmonary tularemia.

The LCt50 values are shown in table II; detailed toxicity data are shown in table A-I.*

*Tables A-I through A-XXI appear in the appendix.

2. Toxic Doses for Molten CS.[2]

The LCt50 values for CS sprayed as molten agent were 42,000, 32,000, 8,000, 17,000, 34,000, 50,000, and 32,000 mg min/cu m for mice, rats, guinea pigs, rabbits, dogs, monkeys, and pigeons, respectively. LCt50 values could not be calculated for swine, sheep, burros, goats, sick goats, chickens, and sick monkeys. Two swine survived Ct's of 65,000 and 86,000 mg min/cu m. Two sheep survived at a Ct of 30,000 mg min/cu m and one of two died at a Ct of 64,000 mg min/cu m.

The combined LCt50 for mice, rats, guinea pigs, rabbits, dogs, monkeys, swine, sheep, goats, and burros is 300,000 mg min/cu m.

The LCt50 values are shown in table II; detailed toxicity data are shown in table A-II.

3. Toxic Doses of CS Dispersed from Acetone.

The only study conducted using acetone as a solvent was performed with guinea pigs.[2] The LCt50 for this species was not reached at 35,000 mg min/cu m. Thus, it is possible that acetone and methylene dichloride dispersions of CS have similar toxicities in guinea pigs.

4. Toxic Doses of CS Dispersed from the M18 Thermal Grenade.[2]

The LCt50 for CS dispersed from the M18 thermal grenade in rats, guinea pigs, and both species combined were 164,000, 36,000, and 79,000 mg min/cu m, respectively.

The LCt50 values are shown in table II; the detailed toxicological data are shown in table A-III.

5. Toxic Doses of CS Dispersed from the M7A3 Thermal Grenade.[3]

The LCt50 values for CS dispersed from the M7A3 grenade are shown in table II; the detailed toxicological data are shown in table A-IV.

6. Inhalation Toxic Doses of a CS2.

The inhalation toxicity of a CS2, containing 95 percent CS, 4.75 percent Cab-O-Sil,* and 0.25 percent hexamethyldisilazane, was determined in monkeys, dogs, rats, and guinea pigs. The additives prevent agglomeration and produce a free-flowing powder which can be dispersed in the dry form. The combined LCt50 for the 4 species is 61,000 mg min/cu m. The LCt50 value for molten CS in the same 4 species is 75,000 mg min/cu m. These values are shown in table II; the detailed toxicological data for CS2 are shown in table A-V.

*Cabot Corporation, Boston, Massachusetts.

C. Toxicity of Repeated Inhaled Doses of CS in Rats and Dogs.[2]

Thirty rats and 4 dogs were exposed to thermally dispersed CS for 4 to 5 minutes per day, 5 days per week, for 5 weeks. The 25-day cumulative Ct to which the dogs were exposed was 17,000 mg min/cu m (the daily Ct was about 680 mg min/cu m). The 25-day cumulative Ct for rats was 91,000 mg min/cu m and the daily Ct was about 3640 mg min/cu m. The rats struggled vigorously during the inhalation of this agent, biting the noses and tails of other rats and scratching their own noses. About one-third of the rats had blody noses by the end of the exposures. There were no changes in blood values in the dogs for sodium, potassium, albumin, or creatinine determined periodically throughout the tests. Five rats died, two following cumulated Ct's of 25,000 mg min/cu m, and three after 68,000 mg min/cu m. Gross pathological examinations of these rats and six rats that were sacrificed after 5 weeks were negative. The exposed rats lost about 1 percent of their body weight while unexposed animals gained about 20 percent during the 5 weeks. There was no significant difference in organ-to-body weight ratios for heart, kidney, lungs, liver, or spleen following the 5-week exposure. It is indicated that repeated exposure did not make the animals more sensitive to the lethal effects of CS.

D. Intragastric Toxicity of CS and CS2 in Rabbits and Rats.

The intragastric toxicities of CS and CS2 were determined in the rabbit and rat.* The agents were administered as water or alcohol/water suspensions containing 250 and 200 mg/cc, respectively, for the rabbit and rat. The CS2 suspension contained 20 percent ethanol in order to wet the material and to maintain a suspension comparable to untreated CS. Dosing was accomplished by injecting the suspensions through an esophageal catheter; the residues remaining in the syringe and tubing after injection were washed into the stomach with a small amount of water. The rats and rabbits used were deprived of food for 24 hours before dosing.

The resultant LD50 values are shown below:

LD50 Values of CS and CS2 Following Intragastric Administration to Rabbits and Rats

Agent	LD50 (mg/kg)	
	Rabbits	Rats
CS	401 (354-453)	822 (599-1127)
CS2	379 (251-571)	985 (811-1196)

These results indicate that there is little difference between the intragastric toxicities of CS and CS2 in either the rabbit or rat.

*Aerosol Branch, Toxicology Department, Edgewood Arsenal, Maryland. Quarterly Progress Report. July-September 1967.

Table A-VI shows the dose range and a Bliss statistical analysis of the mortality responses to CS and CS2 in the two species tested.

Table A-VII lists signs produced by CS and CS2 in individual rabbits and rats following exposure.

E. CS Feeding Studies.

Six groups of four rabbits each and six groups of four rats each were fed laboratory chow contaminated with varying levels of CS for a 30-day period.* Daily rations of 25 grams of food per rat and 150 grams per rabbit were treated with alcoholic solutions of CS. The intended dose levels presented daily to the two species were 1, 10, 50, 100, 250, and 500 mg/kg, assuming 100 percent consumption of the food. The actual average daily doses of CS are shown in table A-VIII. The average daily food consumption for rats and rabbits is shown in tables A-IX and A-X. Control rats and rabbits were fed uncontaminated chow.

Body weights were recorded on the 1st, 14th, 21st, and 30th days of feeding (tables A-IX and A-X). At the end of the study, all of the rats and rabbits that had received the highest daily doses (250 and 500 mg/kg) were sacrificed for gross and microscopic pathological examination.

The results show that rats and rabbits will continue to eat food that has been contaminated with CS at average daily doses as high as 240 and 205 mg/kg, respectively. On the first day of feeding, the amount of food consumed by both species was, at most CS levels, less than on any of the other 29 days. Possibly, tolerance to the agent developed in this brief period. The food intake following the first 25 hours was consistent for both the rabbit and rat at all dose levels. Weight gains were seen in all six groups of rats and in all but one group of rabbits. This group received the highest intended daily dose of 500 mg/kg. The weight change in rabbits was not significant (100 grams/2.5-kg rabbit). One rabbit that received an average dose of 54 mg/kg/day died on the seventeenth day of feeding. This event occurred over a weekend and the cause of death was not determined by pathological examination. No other signs of toxicity were seen in either species over the 30 day period.

F. Local Application of CS to Rabbit Eyes.

Doses of 5 and 10 mg of CS from a 10 percent solution in methylene dichloride placed in the eyes of two groups of 10 rabbits each caused immediate conjunctivitis, which disappeared in a few hours.[2] There was no corneal damage. A dose of 50 mg of CS in a 50 percent suspension in methylene dichloride did not produce corneal damage to the eyes of any of 10 rabbits. The eyes were treated daily with sodium sulfamyd to prevent secondary infection. The observation period was 14 days.

*Aerosol Branch, Toxicology Department, Edgewood Arsenal, Maryland. Quarterly Progress Report. July–September 1967.

G. Pathology and Cause of Death.

Animals dying after exposure to CS showed increased numbers of goblet cells in the respiratory tract and conjunctiva, necrosis in the respiratory and gastrointestinal tract, pulmonary edema, and occasionally hemorrhage in the adrenals.[2] Death appears to result from the poor transfer of oxygen from the lungs to the blood stream, probably because of the edema, hemorrhage in the lung, and obstruction in the air passages.

H. Human Studies on CS.

1. ICt50 Determinations.

A number of ICt50 values* have resulted from different experiments on CS. The experiments differed in technical details as well as in motivation of the individuals who were exposed. Some exposures were done in wind velocities of 5 mph; others were done in chambers with airflows of less than 1 mph In some experiments, the men were exposed in groups of three to six; in others, single individuals were exposed separately. In some experiments the men were motivated to compete with each other; in other experiments the motivation was of a lesser degree. The concentration of CS varied in the different experiments. Table III shows the technical differences and the ICt50 values resulting from seven experiments. ICt50 calculations were made by two equations:

a. Bliss-Type Straight Regression Line Analysis.

$$\text{Log } t = a + b \log c$$

where:

t = time in seconds
a = intercept
b = slope of the regression line
c = concentration in mg/cu m

b. Curvilinear Regression Line Analysis.

In this method the concentration of CS is related to the number of volunteers (percent of population) responding in a specific time period (30, 60, 90, 120, 150, 180, 210, 240, 270, and 300 seconds). From this data Bliss response-regression lines are developed. From the Bliss lines, concentrations are extracted which produce responses of 16, 30, 50, and 84 percent of the population. The individual percent-response values (i.e., 16 percent) are regressed against all time periods (30 to 300 seconds) using the following equation:

$$\text{Log } c = a + b\,(1/t)$$

where the symbols have the same meaning as above.

*Unpublished data, Aerosol Branch, Toxicology Dept.

Table III. Comparative Effectiveness of CS in Men Exposed under Various Conditions
(Individual Experiments)

Study	Date of Study	Dissemination Method	Exposure Conditions	Concn. Range mg/cu m	No. Men	ICt50[a] a mg/cu m	ICt50[a] b mg/cu m
1	1959	Sprayed acetone solutions	a. Wind tunnel – 5-mph air speed. b. Group exposures – total body. c. No specific psychological motivation techniques used – men briefed before exposure – asked to resist agent to best of their ability.	5-442	78[b]	3.0	4.7
2	1967	Sprayed acetone solutions	a. Wind tunnel – 5-mph air speed. b. Individual exposures – head only. c. No motivation – as for study 1.	0.03-8.0	35	0.1	0.07
3	1968	Sprayed acetone solutions	As for study 1.	0.02-5.4	30	0.3	0.2
4	1968	CS/methylene dichloride solutions dropped into heated cup	a. 20-cu m chamber. b. Group exposures – total body c. No motivation – as for study 1.	0.40-0.90	21	0.7	0.6
5	1968	CS/methylene dichloride solutions dropped into heated cup	a. 20-cu m chamber. b. Group exposures – total body. c. Subjects motivated in groups by psychological techniques.	0.50-28.0	130	12.4	6.9
6	1968	CS2[c] dry powder disseminated by Metronics generator	As for study 3.	0.3-6.7	30	1.4	0.5

[a]60-second tolerance time – a = Bliss Analysis
b = Curvilinear Regression Line Analysis

[b]New calculation made in 1969 using 78 men. Data on remainder of 146 exposures used in figure 1 (1959) were not available in 1969.

[c]CS2 – 95% CS; 4.75% Cab-O-Sil; 0.25% hexamethyldisilazane.

Study 6 in table III is still in progress. At the present writing (August 1968), it is the consensus in the Toxicology Department, Edgewood Arsenal, and the MUCOM Operations Research Group that a range of ICt50 values should be used for CS. The range of concentrations which will incapacitate 50 percent of a population in 1 minute is 0.1 to 10.0 mg/cu m, depending upon the motivation of the population involved. The range is applicable to the maximum degree of motivation produced in laboratory experiments and an upper limit above 10.0 mg/cu m may pertain to greater degrees of motivation which might be encountered in riot or combat situations.

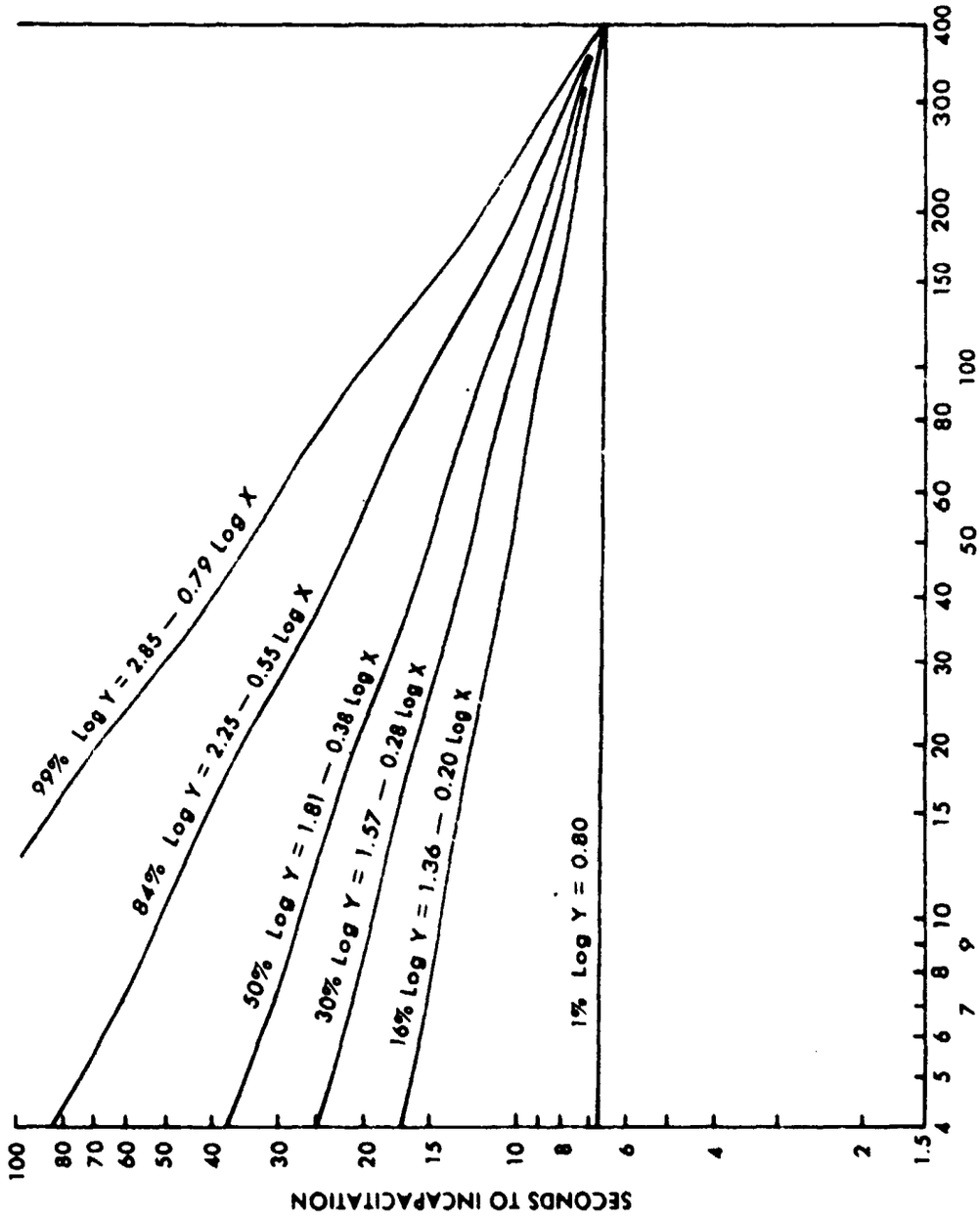
Study 1, table III is an example of an ICt50 test in a laboratory situation on subjects who were strongly motivated by personal interest. The nature of this study is given below. The dose-response, speed-of-action, regression lines derived from this study are shown in figure 1. Healthy adult men were exposed to CS in a wind-tunnel at temperatures of 45° to 80°F and relative humidity of 30 to 80 percent. The usual ambient temperatures and humidity were about 65°F and 30 percent, respectively. The agent was sprayed as a 5 percent solution in acetone into an airstream that flowed at 5 mph. The men breathed at a normal rate while standing facing the wind stream. They were instructed to resist the agent and to remain in the tunnel as long as possible. They were told to emerge from the tunnel of their own volition. The time when the man could no longer tolerate the agent and he was forced to leave the tunnel was considered to be the incapacitation time. Regression lines (1959) were developed for 146 human exposures. These lines are shown in the figure.[5] The incapacitating signs and symptoms in men were intense burning in the eyes, nose, and respiratory tract, profuse lacrimation, salivation, blepharospasm, tightness in the chest, and a feeling of suffocation.

2. Tolerance of Man to CS.

It has been noted that men may work without any sign of discomfort in an atmosphere where CS has gradually accumulated. These CS-containing atmospheres were intolerable to persons entering the contaminated area from fresh air. It was assumed that adaptation developed gradually with a slowly increasing airborne concentration of CS. When the "tolerant" person left the contaminated area for short periods, 10 to 30 minutes, the "tolerance" was lost and re-entry into the contaminated atmosphere resulted in objectionable irritation. In experimental situations when men have been motivated to remain in the cloud for 3 minutes or more a condition of adaptation ensues and the irritant effects subside. Adaptation to CS has been noted at concentrations of 6 mg/cu m or less. It has been noted[6,7] that: (1) men can tolerate 1.5 mg/cu m of CS for at least 90 minutes, and (2) men can tolerate 6 mg/cu m of CS when the concentration is gradually developed during 30 minutes.

In the situation described above, the men were free to leave the contaminated atmosphere of their own volition when they considered the exposure intolerable. The possibility exists that a very high level of adaptation and/or tolerance might develop under conditions of extreme motivation or in situations which prevent escape to clean air. Experiments are in progress to motivate men to resist high concentrations.

Animal experiments indicate that development of high tolerance is possible. In the presence of concentrations of several hundred mg/cu m, animals first became very excited and active, and showed strong indication of irritant action. After several minutes the excitement and activity disappeared and the animals became quiet. Jancso,[8] and Porazasz and Jancso,[9] have shown that animals treated with capsaicin become desensitized for weeks to this and



% = percent of population given positive response.

Figure. Time to Incapacitation in Untrained Men Exposed to CS without Masks

numerous other irritants. Alarie and Tibbits[10] demonstrated that capsaicin given to mice as an aerosol or by subcutaneous injection inhibited the respiratory responses to a variety of chemical irritants. CS was less effective than capsaicin in inhibiting the respiratory response to irritant aerosols.

3. The Influence of Variables on the Time to Incapacitation.[2]

No significant difference from the data contained in the figure for time to incapacitation could be shown:

a. For men exposed to CS dispersed from a miniature M18 grenade
b. For men exposed at 0°F
c. For men over 50 years of age or for those having medical histories of allergies, hypertension, jaundice, or hepatitis

The time to incapacitation was the same as or shorter than shown in figure 1 when the whole body exposures were performed at 95°F, 35 percent relative humidity and at 95°F, 97 percent relative humidity.

4. The Effect of CS on Skin.

The application of CS, in powdered form or in solution, to the skin of sensitive men may cause erythema and vesiculation.[11,12] Aerosols of CS in concentrations of 300 mg/cu m, at 95°F and 95 percent relative humidity, blowing on the bare arms of men for 45 minutes, produced erythema and vesiculation in some.[13] Similar exposures for 30 minutes did not cause skin lesions.

A number of workers in a CS manufacturing and processing plant developed a rash, pruritus, vesicles, and wheals. In some cases, this seemed to represent sensitization with generalized adverse reaction on re-exposure.[12] Bowers concluded that CS is a primary irritant; excessive perspiration at areas of clothing contact contribute to development of lesions. Some individuals develop a hypersensitivity after an initial localized dermatitis and tend to react more rapidly and over a wider area on subsequent exposures.

Other substances known to cause dermatitis among chemical agent workers[12,14] are brombenzyl cyanide, chloroacetone, chloropicrin, trichloromethane, adamsite, chlorine, phosgene, and mustard gas.

Rothberg[15] administered irritants to guinea pigs by the intradermal and topical routes, over a period of several weeks. Following an incubation period of 2 to 3 weeks, the animals were challenged with suberythemal doses. The appearances of erythema, edema, and necrosis during a 72-hour observation period were noted as signs of sensitization. Both CN and CS produced skin sensitization in guinea pigs when administered intradermally or topically. Neither CA (brombenzyl cyanide) or DM produced sensitization when given intradermally.

5. Lethality of CS in Man.

CS is not known to have caused any deaths in man.

6. Toxicity Estimates for CS in Man.

In August 1966[3] the Human Estimates Committee, Research Laboratories (RL), Edgewood Arsenal, Maryland, accepted a value of 52,000 mg min/cu m as the inhalation LCt50 for molten CS in man. The same committee accepted 61,000 mg min/cu m as the inhalation LCt50 in man for CS dispersed from the M7A3 grenade.

The value of 52,000 mg min/cu m is based on a Bliss calculation of data from a single group of animals containing mice, rats, guinea pigs, rabbits, dogs, and monkeys. Some data were available for goats, sheep, swine, and burros, but none of the larger animals were used because the Ct's were high but the deaths were few. Data from the four latter species were not included in the official estimate. When these data were included, the LCt50 was 299,733 mg min/cu m.

The LCt50 estimate for CS from the M7A3 was derived from combined data on rats, guinea pigs, rabbits, dogs, monkeys, swine, and goats.

Other unofficial estimates of LCt50 values for various CS dispersions are as follows (also see table II):

The LCt50 for CS dispersed from methylene dichloride is 1,230,000 mg min/cu m for mice, rats, guinea pigs, and rabbits, combined.

The LCt50 for CS dispersed from the M18 thermal grenade is 79,000 mg min/cu m for rats and guinea pigs.

The LCt50 value for CS2 is 61,000 mg min/cu m for rats, guinea pigs, dogs, and monkeys.

Summaries for the LCt50 doses for the various species and the combined species as affected by the various dispersions are shown in table II. Detailed toxicological data for inhaled CS are shown in tables A-I to A-V.

I. Safety Factors for CS.

Based upon ratios between the official LCt50/tentative ICt50, the safety factors for CS are as follows:

Agent	LCt50 mg min/cu m	ICt50 mg min/cu m	Safety Factor LCt50/ICt50
Molten CS	52,000	0.1–10.0	5,200–520,000
M7A3	61,000		6,100–610,000

The LCt50 of 52,000 mg min/cu m for molten CS excluded toxicity data for goats, sheep, swine, and burros. When the latter animals were included the LCt50 was 300,000 mg min/cu m and the safety factors were 30,000 to 3,000,000.

On the basis of the combined data for mice, rats, rabbits, and guinea pigs, the safety factor for CS dispersed from the methylene dichloride was 123 000 to 12,305,000.

Based upon data in rats and guinea pigs the safety factor for the M18 munition was 7900 to 790,000.

J. Mechanism of Action of CS.

Little is known of the mechanisms involved in the irritant or lethal effects of CS. The following observations and speculations* are reported although their significance or validity cannot be ascertained at this time. The introduction of 2 mmg of CS or CN per ml of human plasma produced reactions in the isolated rat uterus which are indicative of bradykinin release. Enzymatic reactions using benzoyl acetate ethyl ether as a substrate indicate that CS may activate kallikrein in lung and plasma. Kallikrein is an activator of bradykinin.

The lungs of animals dying after exposure to CS appear to be low in lipoprotein surfactant as measured tensiometrically. CS may increase the destruction or decrease the synthesis of the surfactant. CS is known to react with dihydrolipoic acid which is required in the synthesis. Liposomal enzymes from damaged tissue may be involved in destruction of the surfactant.

III. TOXICOLOGY OF CN.

A. Toxicity of CN in Animals[2] (General).

1. Animals Used.

Inhalation toxicity studies in mice and dogs were performed in 1918. Studies on mice, rats, and guinea pigs were done in 1958 to 1959. In these studies the CN was dispersed by sublimation, as dry dust, and from solvents. In 1965, studies were performed in rats, guinea pigs, rabbits, dogs, monkeys, swine, and goats. The CN was dispersed from acetone solvent or from the commercial thermal grenade.

The data on mice in the 1918 and 1958 to 1959 studies were so highly variable that statistical analysis indicated that high doses were less lethal than low doses. The data on mice were included in the estimate on combined species.

2. Animal Exposure Times and Observation Periods.[2]

The exposure times ranged from 3 to 160 minutes and the observation periods were 1 to 2 weeks in the 1918 studies, 2 weeks in the 1958 to 1959 tests, and 4 weeks in the 1965 studies.

*Unpublished data, Basic Toxicology Branch, Tox. Dept.

3. Toxicological Signs in Animals.*

The signs produced by CN were similar by all methods of dispersion. During exposure the signs noted were: lacrimation, conjunctivitis, salivation, frothing at the mouth and nose, erythema, and swelling around the eyes, genitalia and extremities, dyspnea, hyperactivity followed by hypoactivity, and death. Erythema was prominent on the abdomen and inner legs of the dog and swine. After exposure all species exhibited dyspnea for 1 to 24 hours. Conjunctivitis and erythema persisted for about 3 to 7 days. The goats appeared emaciated at this time.

B. Toxic Doses for Single Exposures to CN Dispersed by Various Methods.

The detailed toxicity data (1918 to 1959) for inhaled CN, dispersed by thermal sublimation as dry dust or from solvents, are shown in table A-XI.* A summary of the LCt50 values follows:

Animals	No. of Animals	LCt50 mg min/cu m	Slope
Rats	190	8878	1.1
Guinea pigs	106	7984	3.6
Dogs	62	7033	2.7
All three combined	358	6189	1.9

The LCt50's for CN, dispersed from acetone (1965), in rats, guinea pigs, rabbits, dogs, monkeys, swine, and goats were 9500 13,000, 5800, 5600, 18,000, 4400, and 2500 mg min/cu m, respectively (table A-XII). In the same species the LCt50's for CN dispersed from the commercial grenade were 23,000, 15,000, 16,000, 17,000, 11,000, 5500, and 15,000 mg min/cu m, respectively (table A-XIII).

C. Human Estimates of LCt50's for Single Exposures to CN.

In August 1966,[3] all of the toxicity data from 1918 to 1965 on all animals by all laboratory-type dispersions (excluding munitions) were combined and a value of 7000 mg min/cu m was derived as the human estimate for the inhaled LCt50 of CN. The data involved are shown in table II.

In August 1966,[3] the toxicity data for CN dispersed from a commercial grenade for tests involving rats, guinea pigs, rabbits, dogs, monkeys, swine, and goats were combined and a

*Unpublished data, Aerosol Branch, Tox. Dept.

value of 14,000 mg min/cu m was obtained as a human estimate for the inhaled LCt50 of CN. The data are shown in table II.

D. Repeated Exposures to CN (Commercial Grenade).[2]

Twenty guinea pigs and eight monkeys were exposed on 10 consecutive days to Ct's ranging from 2300 to 4000 mg min/cu m of CN. It was expected that each daily dose might kill 5 to 12 percent of the guinea pigs but none of the monkeys. The total accumulated Ct was 31,445 mg min/cu m. This dose would be expected to kill about 70 percent of the guinea pigs and all of the monkeys if given in one exposure. Three guinea pigs died on the 9th day, and one each died on the 10th and 21st day after the first exposure. No more guinea pigs and no monkeys died during the 30-day experimental period. Thus, the toxicity is less than would be expected if the total dose (Ct of 31,000 mg min/cu m) had been given in a single dose.

Eight dogs were exposed on 10 consecutive days to Ct's ranging from 3000 to 7000 mg min/cu m of CN. These daily Ct's might be expected to kill up to 12 percent of the dogs. The total accumulated Ct was 60,000 mg min/cu m. This would be expected to kill most of the dogs if given in one exposure. One dog died on the 22nd day of the experiment. No other deaths occurred during the 30-day experimental period The death could have been expected from one of the 10 exposures. The number of deaths did not approach that which would be expected if the total dose had been given during one exposure.

Twenty guinea pigs, eight dogs, and eight monkeys were exposed on 10 consecutive days to Ct's ranging from 4200 to 13,000 mg min/cu m. These doses would be expected to kill 13 to 49 percent of the guinea pigs, 3 to 38 percent of the dogs, and 0 to 70 percent of the monkeys. The total accumulated Ct was 88,000 mg min/cu m. Had this dose been given in one exposure, almost all the animals of all three species would be expected to die, but the death rates were somewhat lower than would be expected for the largest single dose. None of the death rates approached those which would be expected from the total accumulated dose, if this dose were given in one exposure.

Thus, there was little evidence of cumulative toxicity in any of these experiments. The detailed toxicological data are shown in table A-XIV.

E. Local Application of CN to Rabbit Eyes and Skin.[2]

CN suspended in corn oil (10 to 100 mg/cc) and placed in rabbit eyes caused no noticeable effect in doses of 0.5 mg, transitory conjunctivitis at 1.0 mg, and corneal opacity in doses of 5.0 mg per eye.

CN in corn oil (100 mg/cc) produced erythema and necrosis of the skin of the back in some rabbits in doses of 5 mg of agent.

F. Pathology Following Inhalation of CN in Animals.[2]

Pathological findings in animals that died following exposure to aerosols of CN are as follows:

Dogs -- congestion, edema, emphysema of the lungs, membranous tracheitis, bronchitis, bronchopneumonia

Rats, mice, guinea pigs -- pulmonary congestion, edema, bronchopneumonia, occasional hemorrhage in adrenals

G. Cause of Death in Animals.[2]

The primary cause of death following CN inhalation is attributable to the lung damage.

H. Lethality of CN in Man.[2]

1. Signs in Man.

A few deaths have occurred in man following exposure to CN in inclosed spaces. All exposures were the result of police action. A.A. Stein and Kirwan[17] give this description of one case.

"On admission to the hospital the patient was agitated and under restraints. His clothes and body smelled of tear gas. His temperature was 99°F; pulse 80; respiration 24; blood pressure 130/80. The conjunctiva were suffused. The pupils were small and unreactive. There was an abundance of mucoid discharge from both the nose and the mouth. By auscultation the chest was clear. However, the heart had an irregular rhythm. The cardiogram was interpreted as within normal limits but with occasional premature ventricular contractions. The neurological examination was unremarkable except for the presence of the Babinski reflex.

He remained in a semicomatose condition for approximately 12 hours and then suddenly developed pulmonary edema and died."

2. Pathology of CN in Man.

Pathology noted in men dying after inhalation exposure to CN includes the following:

Gross examination - Swollen mucosa of trachea and bronchi. Edema of the lungs. Intra-alveolar hemorrhage. Petechiae in the stomach.

Microscopic examination -- Necrosis of the respiratory mucosa with formation of pseudomembrane. Congestion, swelling, edema, and inflammatory cell infiltration of the submucosa. Desquamation of the bronchioles. Congestion of the alveolar capillaries. Brochopneumonia.

3. Cause of Death Following CN Exposures in Man.

Deaths following CN exposures in man have been attributed to damage to the respiratory system as follows:

Medical Authority	Stated Cause of Death
Gonzales[18]	Secondary bronchopneumonia from inflammation of air passages
Stein[17]	Acute pulmonary edema

I. Estimates of Effectiveness, Lethality, and Safety Factors of CN in Man.

1. Effectiveness, ICt50.

Technical Manual 3-215* states that the median incapacitating dose for CN is 80 mg min/cu m. This value is for a 1-minute exposure and is taken from EACD 108.[19] The dose was calculated from data which appear in EACD 130.[20] Aerosols of CN were dispersed by dropping solutions on a hot-plate. The Ct values were derived nominally. The ICt50 value as reported in EACD 130 was 35 mg min/cu m for a 1-minute exposure. Data on human exposures, which are given in TM 24-18 [21] indicate that the ICt50 for a 0.5 to 2.0 minute exposure would be greater than 80 mg min/cu m. In the 1958 experiments, the CN was dispersed from acetone solutions without heat. The airborne material was analyzed by a spectrophotometric method.

The ICt50 values calculated from these data[21] and reported by C.L. Punte et al,[22] were 213, 119, and 93 mg min/cu m for exposures of 1, 2, and 3 minutes, respectively. D. Crichton et al[23] (these data are also reported in TM 24-18) states: "...at relatively high concentrations of 2 ppm, CN produces lachrymation and some blepharospasm, which begins to decrease in severity when the exposure has lasted longer than about 3 minutes. Subjects have remained in an atmosphere of 2 ppm for 8 minutes without distress and could have remained longer." This statement was repeated as follows by Trouern-Trend and Crichton:[24] "Observers were incapacitated after a 40-second exposure to a concentration of 7.8 mg/cu m of CS (Ct = 5.2 mg min/cu m) but were not incapable of activity after an 8-minute exposure to a concentration of 14.7 mg/cu m of CN (Ct = 116 mg min/cu m)."

Tests in September 1965,[3] when the compound was dispersed in cold acetone spray and spectrophotometric analysis was used, yielded an ICt50 of about 40 mg/cu m for exposures of 1 minute or less. The ICt50 for men exposed to CN dispersed from the commercial grenade was 20 mg/cu m for 1 minute or less.

*Military Chemistry and Chemical Agents. p 34. December 1963.

ICt50 for CN in Man

Dissemination Type	No. of Men Responding	Time to Response sec	ICt50 mg min/cu m
Acetone spray	10/17	9–40	40
Commercial grenade	10/17	15–43	20

A concentration range of 20 to 213 mg min/cu m would be intolerable to 50 percent of a population in 1 minute. The exact value would be influenced by the motivation of the individuals.

2. LCt50.

TM 3-215[25] gives the following: "Median lethal dosage. No exact data but believed to be about 11,000 mg min/cu m." C.A. Ransom and F.B. Bogart[26] gave the lethal concentration for dogs for 1/2-hour exposure as 0.34 mg/l. Wells and Eldridge[27] quoted the minimal lethal concentration for CN as 0 85 mg/l for a 10-minute exposure. The same paper gives data and states that the minimal lethal concentration for mice is 0.04 mg/l for a 300 minute exposure. No chemical analysis of the airborne material was performed. NDRC Informal Monthly Progress Report No. 9-4-1-2[28] shows deaths in 0/20 and 12/20 mice after 10-minute exposures at concentrations of 0.66 and 2 56 mg/l of CN. An LCt50 of 800 mg min/cu m and an MLD (Minimum Lethal Dose) of 400 mg min/cu m for mice were given by Gongwer et al.[21] Punte et al[29] reported LCt50's of 3700, 73,500, and 3500 mg min/cu m for rats, mice, and guinea pigs, respectively.

The above data made the derivation of a human estimate for the LCt50 for inhaled CN difficult, and occasioned the TM 3-215 statement of "no exact data" on lethal dosage.[25]

For the purpose of the present report, all available original data were obtained for studies conducted from 1918 to 1965. These data were analyzed by the method of Bliss and regression lines were calculated. The combined toxicity data for "pure" CN dispersed from molten agent, dry dust, or solvent systems and inhaled by rats, guinea pigs, rabbits, dogs, monkeys, swine, and goats yield an $LCt50^3$ of 7000 mg min/cu m. The $LCt50^3$ for CN dispersed from the commercial grenade in rats, guinea pigs, rabbits, dogs, monkeys, swine, and goats was 14,204 mg min/cu m. The LCt50's of 7000 and 14,000 mg min/cu m were accepted as RL human estimates[3] for CN dispersed in the "pure" form and by thermal grenades (with burning characteristics of the commercial grenade), respectively.

3. Safety Factors for Inhaled CN.

On the basis of the data presented in this report the safety values for inhaled CN are as follows:

Agent	LCt50 mg min/cu m	ICt50 mg min/cu m	Safety Factor LCt50/ICt50
"Pure CN"	7,000	20 – 213	33 – 350
Commercial thermal grenade	14,000		65 – 700

IV. TOXICOLOGY OF DM.

A. Toxicity of DM in Animals.

One of the striking features of inhalation toxicity studies on DM is the variation in the results of different experiments. The British "Red Book," 1940,[30] gave no toxicity values for this compound in animals because of the inconsistency of results. Perhaps the methods of dispersion of the aerosols and the methods for measuring airborne concentrations contributed to the variability.

The data used in this report include dispersions of molten DM to dogs (1919), dry dust dispersions to mice, rats, and guinea pigs (1957), acetone dispersions to mice, rats, guinea pigs, dogs, and monkeys (1963 to 1964), and acetone and munition (M6A1 thermal grenade, commercial grenade) dispersions to rats, guinea pigs, rabbits, dogs, monkeys, goats, and swine (1965). The ICt50 values are shown in table II. Detailed toxicological data are shown in tables A-XV to A-XIX.

1. Toxicological Signs in Animals.

The toxicological signs in animals were similar for all types of dispersions and were as follows:

a. Mice, Rats, and Guinea Pigs.

Immediately upon exposure to DM the animals were hyperactive. Within a few minutes lacrimation and salivation were observed After 5 to 15 minutes the excitement was generally supplemented by lethargy and labored breathing. The latter signs often persisted for 1 or 2 hours after exposure. The other signs usually subsided within 5 to 10 minutes after removal of the animals from the contaminated atmosphere.

b. Dogs.

Immediately upon exposure the dogs became extremely restless. Jumping and barking were noted. Salivation, retching, and vomiting occurred. The animals became ataxic and some were unable to maintain standing posture. Upon removal from the chamber, they

were hypoactive, they pawed their faces; gagging and vomiting occurred periodically for 24 hours. They consumed little food or water for about 7 days and they became emaciated. After 7 days, the animals resumed normal eating and drinking and improved in appearance. Most deaths occurred in the first week after exposure.

c. Monkeys.

During exposure, salivation, vomiting, rhinorrhea, ataxia, and difficulty of breathing were noted. Upon removal from the chamber the animals exhibited wheezing, ptosis, and lethargy. Coughing and vomiting persisted for 24 to 48 hours. After 24 to 48 hours, open lesions were noted on the face and around the eyes, possibly due to pawing by the animal. Prior to death the monkeys layed faced down, and breathing seemed to be depressed.

d. Goats.

Signs which occurred during exposure were hyperactivity, shaking of the head, rearing on the hind legs, licking, chewing, frothing at the mouth, ataxia, convulsions, bloating, and death. During the week following exposures, the animals were hypoactive, knelt on their forelegs, gagged, and vomited. The goats seemed weak. They collapsed and convulsed prior to death. All goats were bloated upon death.

e. Swine.

The signs noted during exposure were salivation, frothing at the mouth, ataxia, and irregular breathing. During the first 14 days after exposure the pigs had breathing difficulty, lost weight, and appeared emaciated; some died.

2. Inhalation Toxic Doses of DM Following Single Exposures and Human LCt50 Estimates.

Various estimates based on animal data have been made for the expected LCt50 of DM for man. The estimates were based on different types of aerosol dispersions and differences in the number of animals and numbers of animal species involved.

a. Pure DM.*

An estimate of the toxicity of inhaled DM (pure agent disseminated by laboratory dispersion methods) was established at Chemical Research and Development Laboratories (CRDL), Edgewood Arsenal, Maryland, in 1959. This estimate used toxicity data on mice and guinea pigs reported in TM 24-18[21] and data on dogs reported in EACD 145.[32] The LCt50's for the various species considered as the basis for the estimate differed widely. Since there was no way to ascertain the lethality in man or to relate the toxicity in man with any of the animal

*Pure DM – Agent, dispersed as a single entity, dispersed as a dry dust, from solvent sprays, or by volatilization – condensation.

species studied, all of the toxicity data was combined and a composite lethality dose-response regression line for mammals was determined. A value of 14,000 mg min/cu m for a single exposure was established as the predicted LCt50 for mammalian species including man.

Other inhalation testing with pure DM disseminated by laboratory methods was performed between 1959 and 1964. The combined LCt50 value for pure DM in all species tested, based on all experiments performed between 1918 and 1964 was calculated to be 15,052 (11,040 to 22,941) mg min/cu m. Table A-XV shows the individual experiments used as the basis for the calculation of this value. Table A-XVI shows the Bliss Statistical analysis of the data for the combined mortalities of each species, all rodents, all nonrodents, and all species combined.

In May 1965 a series of LCt50 determinations were conducted with DM disseminated from 10 percent acetone solutions in the rhesus monkey, dog, swine, goat, rabbit, rat, and guinea pig. The LCt50 determined for pure DM was 12,306 (10,283 to 14,726) mg min/cu m, based on the combined mortality responses in the seven species tested. These data, with a Bliss Statistical analysis of the dose responses of the individual species, all rodents, all nonrodents, and all species, are shown in table A-XVII.

When the mortality responses for all species tested with pure DM between 1918 and 1965 are combined, the resulting LCt50 is 11,309 (9548 to 13,600) mg min/cu m. Table A-XVIII shows the Bliss Statistical analysis of these data.

Based on the analysis of all animal toxicity determinations performed with DM disseminated by laboratory methods, the current Research Laboratories, estimated human LCt50 of inhaled, pure DM to be 11,000 mg min/cu m (table A-XVIII).

b. Munition Dispersion of DM.

During the period from May to August 1965, inhalation toxicity testing was conducted with military and commercial DM munitions.* The modified M6A1 DM and the commercial DM grenades were tested in the monkey, dog, swine, goat, rabbit, rat, and guinea pig. Based on these studies, the combined, all species, LCt50 values are 43,808 (24,549 to 78,178) and 34,683 (36,245 to 39,773) mg min/cu m for DM aerosols generated from the M6A1 and the commercial thermal grenades, respectively. The mortality responses and Bliss Statistical analysis of these data are shown in tables A-XIX and A-XX.

The current Research Laboratories estimated human LCt50's of inhaled DM, generated from the M6A1 and commercial grenades, to be 44,000 and 35,000 mg min/cu m, respectively.

3. Repeated Exposures to DM.*

Monkeys, dogs, and guinea pigs were exposed on 10 consecutive days to DM aerosols (commercial thermal grenade). The daily doses were approximately at the LCt50 level. A similar group of animals was exposed at approximately the LCt20 to LCt25 level on each of 10 days. In both cases, the accumulated doses would be expected to kill all animals if given in a single exposure.

*Unpublished data, Aerosol Branch, Tox. Dept.

The low dose killed 5/8 monkeys, more than would be expected if any one of the exposures were given in a single exposure. It is a lower mortality than would have been expected of the total accumulated dose. The deaths among the dogs and guinea pigs receiving the low dose was not greater than would have been expected from any of the single exposures and far less than would be expected of the accumulated dose.

The deaths in monkeys and guinea pigs receiving the high dose were slightly greater than would have been expected for the single dose. The deaths in dogs were less than that which would have been expected of the single dose. There was little indication of cumulative toxicity due to the repeated exposures. Detailed toxicological data are given in table A-XX.

4. Local Application of DM to Rabbit Eyes and Skin.[2]

A suspension of DM in corn oil was administered intraocularly to groups of six rabbits each at doses of 0.1, 0.2, 0.5, 1.0, and 5.0 mg per eye. All animals were observed from 8 to 14 days. A dose of 0.1 mg produced no noticeable signs; 0.2 mg produced a transitory conjunctivitis; 0.5 mg caused a transitory conjunctivitis and blepharitis; 1.0 and 5.0 mg produced corneal opacity which persisted during the 14-day observation period.

Suspensions of DM in corn oil (100 mg/ml) were placed upon the clipped backs of rabbits. Doses of 1, 10, 50, 75, and 100 mg per animal were administered to groups of six rabbits each. Doses of 10 mg and above produced necrosis.

5. Pathology Following Inhalation of DM in Animals.[2]

Pathological findings in animals that died following inhalation of DM include the following:

1. Dogs

   Hyperemia of the larynx and trachea. Edema and congestion of the lung. Bronchopneumonia

2. Rats, Mice

   Atelectasis, emphysema, reticular cell proliferation, respiratory epithelial proliferation, interstitial leucocytic infiltration of the bile duct.

3. Monkeys

   Pneumonitis, ulcerative bronchiolitis and tracheitis, edema and congestion of the lungs.

4. Guinea Pigs

   Bronchitis, tracheitis.

The primary cause of death is lung damage.[2]

B. Incapacitating Effects of DM in Man.[2]

1. General.

The onset of signs from DM may be almost immediate or may be delayed several minutes. The initial effects are irritation; a burning sensation and pain in the eyes, nose, throat, and respiratory tract; uncontrollable cough; violent and persistent sneezing; lacrimation and copious flow of saliva. The conjunctiva, nose, and pharyngeal wall become congested. The signs of irritation subside after 20 to 30 minutes after termination of DM exposure. Headache, depression, perspiration, chills, nausea, abdominal cramps, vomiting, and diarrhea may appear about 30 minutes after exposure and persist for several hours.

2. ICt50 for Irritant Effects of DM.[2]

There is controversy as to the ICt50 for irritant effects of DM in man.

A dose-effect graph for intolerable concentrations of DM was developed by Lawson and Temple[31] in 1922 and included concentrations of 22.3, 0.7, 0.2, and 0.14 mg/cu m for exposure periods of 1, 5, 15, and 60 minutes, respectively. In this test an alcoholic solution of DM was dropped into a heated tube and the cloud produced was conducted into a mixing chamber by a stream of nitrogen. The men breathed the cloud through a 1919-type mask connected to the chamber by a 3-way valve. The concentrations of DM were estimated. Subjects were told to keep the mask on until there was feeling of distress, but due to the nature of the gas, they were not expected to fight it to the limit of their endurance. It is likely that the median incapacitating doses of 22 mg min/cu m for a 1-minute exposure, and 8 mg min/cu m for a 60-minute exposure, as reported in TM 3-215,[25] December 1963, were derived from graphs of Lawson and Temple.

Results of field tests[32] during the early 1920's indicated that some observers tolerated Ct's of DM of 83 to 155 mg min/cu m. Although the quantitative aspects of these field exposures are somewhat doubtful, there appears to be some discrepancy between the doses of Lawson and Temple and those measured in the field.

Other human exposures at CRDL in 1958[21,22] indicated that men could tolerate concentrations of 22 to 92 mg/cu m for 1 minute or more. In the latter tests, the subjects were told to resist the agent.

It is indicated that the ICt50 value for the irritant effects of DM will vary in different men and in different situations. A concentration range of 22 to 220 mg/cu m would appear to be intolerable for 50 percent of a population in 1 minute. These values are applicable to experimental situations.

3. ICt50 for Systemic Effects of DM.

An important consideration concerning DM is the "persistent incapacitating action." This usually refers to malaise, nausea, and vomiting. The available data indicate that the ICt50 for these effects has not been achieved in controlled exposures of man.

The earliest studies in man were reported by Lawson and Temple[31] and further amplified in the digest of Craighill and Folkoff.[32] In these studies, nausea was produced in three of 21 men (respective Ct's = 6, 7.2 and 12 mg min/cu m) exposed to a concentration of 2 mg/cu m for 140 seconds to 15 minutes, or Ct's ranging from 4.6 to 30 mg min/cu m. Nausea occurred in two of 22 men (respective Ct's = 13.75 and 25.0 mg min/cu m) exposed to 5 mg/cu m for periods of 45 seconds to 12.5 minutes, or Ct's ranging from 3.75 to 62.5 mg min/cu m.

In the experiments performed in 1958,[21,22] nausea and vomiting were seen infrequently. Of 25 subjects exposed to Ct's ranging from 5 to 144 mg min/cu m, only two became nauseated. They were exposed at Ct's of 18 and 22 mg min/cu m.

During October 1966 and April 1967, The Aerosol Branch and Clinical Investigation Branch, Medical Research Laboratory[1] exposed 33 men at Ct's ranging from 7.1 to 236 mg min/cu m. Twelve of these men experienced some degree of nausea and one of the 12 vomited. The Ct's causing nausea were 15, 18, 37, 39, 43, 49, 53, 58, 78, 94, 192, and 236 mg min/cu m. The dose causing vomiting, as well as nausea, was 49 mg min/cu m. Where these effects did occur, the average time of onset was approximately 5 minutes (40 seconds to 20 minutes) and the average duration, approximately 15 minutes (5 to 30 minutes).

At dose levels studied in man, the results were highly variable and lacked statistical significance. The data indicate that the ICt50 for systemic effects was not reached. Possibly there was an insufficient number of exposures at Ct's above 200 mg min/cu m. Exposure of additional volunteers at Ct's above 200 mg min/cu m was deemed inadvisable in the 1966 to 1967 study. A similar decision has been made in the 1958 tests on men. In view of these decisions it was necessary to base the estimation on data from animal experimentation.

Several types of animal tests were performed to determine the inhalation Ct of DM which would produce nausea, vomiting or impaired ability to perform a learned task. These tests were as follows:

a. Observation of gross signs in dogs*,**
b. Measure of gastrointestinal activity by use of electrodes implanted in the stomach of dogs*
c. Observation of gross signs in monkeys**
d. Increase in avoidance latency as shown by the visual discrimination test†,[33]

Based on (1) nausea or vomiting in man, (2) vomiting in dogs, (3) increased gastrointestinal activity in dogs, (4) drowsiness in dogs, and (5) the results of the VDT test in monkeys, the ICt50 human estimate could be placed at 250 to 387 mg min/cu m. Inasmuch as increased gastrointestinal activity and vomiting in dogs are more applicable to the nausea experienced by man, the ranges for human estimates could be narrowed to 350 to 390 mg min/cu m.

*Farrand, R.L., Ballard, T.A., Vick, J., MAJ, Harvey, J., and Graf, C. The Effects of Inhaled DM on the Gastrointestinal Activity of Dogs. Research Laboratories. October 1966–April 1967. Contained in reference 1.

**Farrand, R.L., Ballard, T.A., Harvey, J., Graf, C., Gross Signs of Inhaled DM in Dogs and Monkeys. Research Laboratories. October 1966–April 1967. Contained in reference 1.

†Farrand, R.L., Ballard, T.A., Harvey, J., and Graf, C. The Effects of Inhaled DM on the Visual Discrimination Test (Performance of a learned task) in Rhesus Monkeys. Research Laboratories. October 1966–April 1967. Contained in reference 1.

In September 1967, the Research Laboratories Human Estimate Committee[1] established 370 mg min/cu m as the ICt50 for systemic actions (nausea and vomiting) of inhaled DM for man.

C. Lethality of DM in Man.[2]

1. General.

One death has been attributed to inhalation of DM. This followed the operation of a DM generator in a barracks which exposed 22 sleeping men. The estimated concentration was 1130 to 2260 mg/cu m. The exposure period was 5 to 30 minutes, according to different reports. The Ct's would be 5650 to 11300 mg min/cu m for the 5-minute exposure and 33,900 to 67,800 mg min/cu m for the 30-minute exposure.

Post mortem examination of the victim revealed emphysema of the subcutaneous tissues of the neck, the mediastinum, pleura, and pericardium. Emphysematous bullae were scattered over the lungs. The lungs were springy and a bluish discoloration was noted. No consolidation, edema, or casts in the bronchi were noted when the lungs were cut.

Histological study showed edema and congestion of the epiglottis, superficial ulceration and acute diffuse inflammation of the trachea and bronchi, pseudomembrane formation in the trachea and bronchi, lung congestion, edema, and hemorrhage, and bronchopneumonia.

Death can be attributed to damage of the lungs and respiratory system.

2. LCt50 Dose Estimates for DM.

An estimate for the toxicity of inhaled DM in man was established at CRDL in 1959. This estimate used toxicity data on mice and guinea pigs reported in TM 24-18,[21] and data on dogs reported in EACD 145.[32] All of the toxicity data were combined to yield a composite lethality dose-response graph for "mammals" including man. The LCt50 for a single exposure was 14,000 mg min/cu m.

More recent studies have greatly increased the number of animals and species. The LCt50's for "pure" DM (dispersed as molten agent, dry dust, or from solvent) in mice, rats, guinea pigs, dogs, monkeys, swine, and goats are shown in table II. The combined LCt50 for "pure" DM is 11,309 mg min/cu m.

Similar data for DM dispersed from the M6A1 thermal grenade and from the commercial thermal grenade are also shown in table II. The combined LCt50's for the two munitions in "mammals" are 43 809 and 34,683 mg min/cu m, respectively. Until 1965 no DM munitions had been studied for inhalation toxicity. It is to be noted that the toxicities are similar for the two munitions and that both produce aerosols that appear less toxic than those produced from "pure" DM.

D. Safety Factors for Inhaled DM.

On the basis of data presented in this report the best safety factors for inhaled DM are as follows:

Agent	LCt50 mg min/cu m	ICt50 mg min/cu m	Safety Factors LCt50/ICt50
Laboratory dispersions	11,000		50 – 500
M6A1 grenade	44,000	22 or 220	200 – 2,000
Commercial grenade	35,000		160 – 1,600

A detailed review on "The Toxicology of DM"[34] was published in October 1967.

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Table A-1. CS Inhalation Toxicity (Dispersed from 10 Percent Solution in Methylene Dichloride)

Species	Source	Concentration mg/cu m	Exposure Time min	Ct mg min/cu m	Mortality	Times to Death* day	Statistical Analysis				
							P	ED(P)	Lower Limit	Upper Limit	Std Error of Slope
Mice	CWLR 2360 Feb 1960	900	10	9,000	0/20	–	1	36,380	5,633	234,947	
		1,650	20	33,000	0/20	–	16	185,581	37,939	907,787	
		2,566	30	77,000	1/20	5(1)**	30	329,856	14,880	7,311,963	1.88
		2,625	40	105,000	0/20	–	50	626,571	5,712	68,732,784	
		2,200	50	110,000	1/4	5(1)	84	2,115,471	980	4,567,549,800	
							99	10,791,251	95	12,239,918,100,800	
Rats	CWLR 2360 Feb 1960	500	4	2,000	0/10	–	1	5,350	99	288,736	
		800	5	4,000	0/10	–	16	107,146	3,681	3,118,801	
		570	7	4,000	0/10	–	30	308,612	704	135,235,260	1.02
		500	10	5,000	0/10	–	50	1,004,427	115	8,777,741,300	
		539	13	7,000	0/10	–	84	9,145,852	4	23,699,228,000,000	
		1,125	8	9,000	0/10	–	99	188,560,190	.04	xxxxxxxxxx	
		1,100	10	11,000	1/10	4(1)					
		1,500	12	18,000	0/10	–					
		1,267	15	19,000	1/10	5(1)					
		1,350	20	27,000	1/10	4(1)					
		2,455	11	27,000	0/10	–					
		2,055	18	37,000	1/10	7(1)					
		1,433	30	43,000	1/10	8(1)					
		1,343	35	46,000	0/10	–					
		1,178	45	53,000	1/10	12(1)					
		1,967	30	59,000	1/10	5(1)					
Guinea Pig	CWLR 2360* Feb 1960	600	5	3,000	0/10	–	1	4,060	1,921	8,581	
		500	6	3,000	0/10	–	16	16,262	10,952	24,146	
		800	5	4,000	0/10	–	30	26,541	16,975	41,497	2.21
		455	11	5,000	0/10	–	50	45,838	25,097	83,719	
		538	13	7,000	0/10	–	84	129,202	47,438	351,900	
		700	10	7,000	0/10	–	99	517,561	105,049	2,549,947	
		800	10	8,000	0/10	–					
		1,000	10	10,000	2/10	1(1), 6(1)					
		917	12	11,000	1/10	1(1)					
		800	15	12,000	0/10	–					
		509	55	28,000	7/10	1(2), 6(5)					
		1,400	60	84,000	5/10	1(1), 3(1), 5(1), 6(2)					
Rabbits	CWLR 2360 Feb 1960	1,000	10	10,000	0/4	N/A					
		667	15	10,000	0/4						
		667	15	10,000	0/4						
		800	15	12,000	0/4						
		650	20	13,000	0/4						
		1,000	15	15,000	0/4						
		1,100	30	33,000	0/4						
		1,044	45	47,000	0/4						
Pigeons	CWLR 2360 Feb 1960	333	15	5,000	0/4		1	15,179	2,491	92,476	
		800	10	8,000	0/4		16	129,761	17,787	946,614	
		1,300	20	26,000	0/4	–	30	276,749	71,207	1,075,604	1.43
		1,733	30	52,000	0/4		50	644,207	159,333	2,604,631	
		1,571	35	55,000	1/4	3(1)*	84	3,198,198	82,996	123,340,490	
		1,933	45	87,000	0/4		99	27,340,416	61,563	12,141,978,000	
All species combined (mammals only)							1	3,047	200	7,484	
							16	94,609	50,524	477,333	
							30	318,120	122,037	6,036,407	.24
							50	1,230,497	305,310	109,395,350	
							84	16,003,946	1,483,606	27,803,867,000	
							99	496,884,700	15,738,627	47,322,570,000,000	

*14 day observation
**Number in parentheses indicates number of animal deaths on day indicated.

Table A-II. CS Inhalation Toxicity (Sprayed as Molten Agent)

Species	Source	Concentration mg/cu m	Exposure Time min	Ct mg min/cu m	Mortality	Times to Death* day	Statistical Analysis				
							P	ED(P)	Lower Limit	Upper Limit	Std Error of Slope
Mice	CWLR	1,200	10	12,000	0/20	–	1	9,899	2,177	45,004	
	2360	1,100	20	22,000	7/20	7(1)**, 8(3), 9(3)	16	22,578	14,566	34,996	
	Feb 1960	900	30	27,000	2/20	7(2)	30	30,205	25,668	35,543	3.72
		800	40	32,000	5/20	5(2), 9(3)	50	41,790	26,829	65,093	
		740	50	37,000	5/20	5(1), 6(3), 7(1)	84	77,350	22,310	268,180	
		683	60	41,000	14/20	5(4), 8(5), 9(4), 13(1)	99	176,419	17,052	1,825,257	
	REMARKS Mixture dispersion - UV analysis - 260 mμ										
Rats	CWLR	560	25	14,000	1/10	1(1)	1	7,172	2,611	19,704	
	2360	543	35	19,000	2/10	1(2)	16	16,973	11,257	25,952	
	Feb 1960	489	45	22,000	3/10	2(1), 5(1), 4(1)	30	23,004	17,966	29,454	3.56
		454	55	25,000	5/10	1(3), 3(2)	50	22,293	25,265	41,267	
		500	60	30,000	2/10	1(2)	84	61,443	32,551	115,979	
		500	80	40,000	6/10	1(1), 2(2), 6(3)	99	145,405	41,517	509,249	
		500	90	45,000	9/10	1(1), 3(2), 7(2), 11(3)					
	REMARKS As above										
Guinea Pig	CWLR	400	5	2,000	1/10	7(1)	1	811	168	3,921	
	2360	400	10	4,000	2/10	7(1), 8(1)	16	3,095	1,510	6,345	
	Feb 1960	400	15	6,000	4/10	1(2), 6(2)	30	4,964	3,138	7,854	2.29
		500	20	10,000	3/10	1(1), 6(1), 7(1)	50	8,410	6,031	11,713	
		400	25	10,000	7/10	2(5), 7(1), 8(1)	84	22,851	10,448	49,982	
		400	30	12,000	7/10	1(4), 5(1), 7(1), 9(1)	99	87,154	16,809	451,894	
		425	40	17,000	8/10	1(7), 3(1)					
	REMARKS As above										
Rabbits	CWLR	250	40	10,000	0/4	–	1	11,534	5,230	25,434	
	2360	267	45	12,000	0/4	–	16	14,620	11,820	18,082	
	Feb 1960	500	30	15,000	1/4	6(1)	30	15,896	13,297	19,004	12.93
		250	80	20,000	3/4	1(1), 2(1), 7(1)	50	17,452	14,317	21,272	
		333	90	30,000	4/4	1(1), 2(1), 3(1), 8(1)	84	20,832	13,714	31,643	
							99	26,406	10,074	69,213	
	REMARKS As above										
Pigeons	CWLR	368	19	7,000	0/4	–	1	13,579	3,656	50,432	
	2360	325	40	13,000	0/4	–	16	22,229	17,923	27,571	
	Feb 1960	511	45	23,000	1/4	5(1)	30	26,454	19,585	35,732	6.22
		300	60	18,000	0/4	–	50	32,121	26,504	38,926	
		353	80	28,210	3/4	<1(2), 1(1)	84	48,413	16,346	131,786	
		600	60	36,000	2/4	5(1), 6(1)	99	75,984	9,882	584,243	
	REMARKS As above										

*14 day observation period

**Number in parentheses indicates number of animal deaths on day indicated

Table A-II. Continued

Species	Source	Concentration mg/cu m	Exposure Time min	Ct mg min/cu m	Mortality	Times to Death* day	Statistical Analysis				
							P	ED(P)	Lower Limit	Upper Limit	Std Error of Slope
Dogs	Aerosol Br 1959	833	20	16,660	0/4	–	1	2,486	.54	113,545	2.06
		508	36	18,276	2/4	5(1),** 10(1)	16	11,200	2,790	42,234	
		649	30	19,475	1/4	12(1)	30	18,662	12,860	27,081	
		520	45	23,424	2/4	1(1), 2(1)	50	33,551	21,298	52,854	
		612	45	27,536	2/4	1(1), 4(1)	84	102,855	14,079	739,760	
		899	40	35,974	2/4	1(2)	99	452,715	5,616	36,491,644	
		797	60	47,828	2/4	1(2), 3(1)					
		909	60	54,530	2/4	1(2)					
	REMARKS: Mulvar Dispersion – UV Analysis – 260 mμ										
Monkeys	Aerosol Br 1959	469	24	11,246	1/4	5(1)	1	43	.04	42,684	0.76
		381	45	17,130	2/4	1(2)	16	2,446	270.0	22,186	
		673	30	20,176	2/4	1(2)	30	10,192	3,636	28,566	
		612	45	27,536	1/4	5(1)	50	59,889	12,892	207,482	
		649	60	41,930	1/4	1(1)	84	1,025,906	29,758	35,367,900	
		941	60	56,499	3/4	1(3)	99	58,511,908	17,775	192,605,810,880	
		1057	60	63,433	2/4	1(2)					
	REMARKS: As above, except MMD = 2.0–3.2 μ										
Pigs	Gassing Br 1959	2157	30	64,701	0/2	–		N/A			
		1434	60	86,048	0/2	–					
	REMARKS: As above										
Sheep	Gassing Br 1959	909	30	29,680	0/2	–		N/A			
		1065	60	63,900	1/2	1(1)					
	REMARKS: As above, except MMD = 3.4 μ										
Burro	Gassing Br 1959	1830	55	36,165	0/2	–		N/A			
		1019	60	61,178	0/2	–					
	REMARKS: As above, except 2.2 -3.5 μ										
Goats	Gassing Br 1959	416	60	24,959	0/4	–	REMARKS: Each group contained two healthy and two sick goats. Goats were made sick by administration of cortisone and infecting with pasteurella multocida or bovine kidney tissue virus. Two were suffering from natural infection. Sick goats had temperatures > 103°F and rales when exposed to CS. Both goats which died had been artificially infected. – MMD = 3.0–6.9 μ.				
		502	60	30,143	0/4	–					
		668	84	37,672	0/4	–					
		672	60	40,330	0/4	–					
		688	60	41,305	0/4	–					
		994	60	59,634	1/4	3(1)					
		1143	60	68,585	1/4	6(1)					
		1691	70	104,363	0/4	–					
Chickens	Aerosol Br	2020	5	10,150	1/4	8(1)		N/A			
		2153	10	21,525	0/3	–					
		1999	15	29,985	1/4	13(1)					
		3253	15	48,795	0/4	–					

Table A-II. Continued

Species or Combination	Probit Statistical Analysis				
	P	ED(P)	Lower Limit	Upper Limit	Std Error of Slope
All Rodents	1	15	.0	7,531,550,700	0.260
	16	1,964	3	1,221,565	
	30	11,054	2,025	60,329	
	50	75,971	1,656	3,484,384	
	84	2,939,094	2	3,458,390,980,000	
	99	392,851,550	0		
All Non-Rodents	1	1,501	70	31,931	0.635
	16	8,694	2,600	29,071	
	30	16,160	8,748	29,851	
	50	32,268	20,176	51,600	
	84	119,766	21,412	669,892	
	99	693,543	19,186	25,070,510	
All Species Combined	1	73	.2	35,206	0.241
	16	3,139	381	25,839	
	30	11,844	5,654	24,812	
	50	52,099	17,967	151,069	
	84	868,715	14,821	50,449,356	
	99	27,214,572	10,715	129,250,980,000	

Table A-III. CS Inhalation Toxicity (Dispersed from the M-18 Thermal Grenade)

Species	Source	Concentration mg/cu m	Exposure Time min	Ct mg min/cu m	Mortality*	Times to Death day	Statistical Analysis				
							P	ED(P)	Lower Limit	Upper Limit	Std Error of Slope
Rats	CWLR 2360 Feb 1960	600	15	9,000	1/10	2(1)**	1	15,207	8,724	26,505	
		454	23	13,000	0/10	–	16	59,301	33,090	106,273	
		562	32	18,000	0/10	–	30	95,870	26,293	349,558	2.25
		1,350	20	27,000	1/10	2(1)	50	163,832	22,312	1,202,969	
		600	45	27,000	0/10	–	84	452,627	17,493	11,916,132	
		567	60	34,000	0/10	–	99	1,765,098	12,463	249,978,980	
		600	75	45,000	1(1)	1(1)					
Guinea Pigs	CWLR 2360 Feb 1960	600	15	9,000	0/10	–	1	2,571	181	36,530	
		454	23	13,000	2/10	2(1), 3(1)	16	11,730	4,698	29,287	
		562	32	18,000	2/10	1(1), 2(1)	30	20,044	13,352	30,090	2.02
		1,350	20	27,000	3/10	3(1), 5(1), 1(1)	50	36,439	20,165	65,847	
		600	45	27,000	7/10	3(2), 4(1), 5(3), 8(1)	84	113,197	17,864	717,282	
		567	60	34,000	5/10	2(1), 4(3), 5(1)	99	516,500	13,920	19,164,678,000	
		600	75	45,000	5/10	1(2), 2(1), 3(1) 8(1)					
Rats and Guinea Pigs	CWLR 2360 Feb 1960						1	3,209	76	136,203	
							16	20,053	11,868	33,883	
							30	38,289	16,809	87,218	1.67
							50	78,778	9,744	636,883	
							84	309,478	3,252	29,450,806	
							99	1,933,710	738	5,065,875,980	

*14 day observation period.
**Number in parentheses represents number of animal deaths on given day.

Table A-IV. CS Munition (M7A3) Inhalation Toxicity

Species	Ct mg min/cu m	Concentration mg/cu m	Exposure Time min	Mortality	Times to Death* hour	Bliss Statistical Analysis				
						P	ED(P)	Lower Limit	Upper Limit	Std Error of Slope
Monkey	264,400	4,265	62	6/6	<2 hrs (6)**	1	43,729	17,650	108,341	1.533
	149,425	3,558	42	4/6	1(2), 2(2)	16	79,121	50,241	124,600	
	119,660	3,739	32	2/6	18,240	30	97,542	69,673	136,557	
	62,400	1,950	32	1/6	600	50	123,195	91,847	165,241	
	55,950	3,730	15	0/6		84	191,820	115,484	318,614	
						99	347,071	131,424	916,559	
Dog	72,160	2,488	29	6/6	18(6)	1	3,298	147	73,927	.765
	62,400	1,950	32	6/6	18(5), 240	16	11,617	2,618	51,558	
	50,050	1,925	26	3/6	4, 18, 28	30	18,119	7,025	46,735	
	33,760	1,688	20	2/6	18(2)	50	29,748	18,481	47,886	
	27,680	1,991	14	1/6	24	84	76,177	24,530	236,560	
	12,975	2,595	5	3/6	72, 108, 144	99	268,343	17,416	4,134,613	
	4,216	1,054	4	0/6	–					
Swine	72,160	2,488	29	6/6	1/2(6)	1	5,995	709	50,687	1.959
	67,300	1,819	37	6/6	1/2(6)	16	10,869	3,677	32,128	
	34,070	3,786	9	5/6	2(3), 96, 456	30	13,409	6,426	27,981	
	21,660	3,094	7	5/5	18, 24, 360, 456, 648	50	16,949	11,098	25,886	
	13,975	2,595	5	1/6	18	84	26,430	13,100	53,323	
	4,216	1,054	4	0/6	–	99	47,917	8,572	267,845	
Goat	82,930	2,592	32	6/6	1/2(1), 3/4(3), 18(2)	1	13,692	5,285	35,471	1.201
	67,300	1,819	37	4/6	1/2(4)	16	28,134	17,617	44,928	
	62,400	1,950	32	4/6	18, 144(2), 192	30	36,277	26,072	50,476	
	43,900	2,927	15	1/6	192	50	48,171	37,115	62,519	
	34,070	3,786	9	2/6	408,672	84	82,478	51,259	132,710	
	21,660	3,094	7	1/5	456	99	169,475	64,851	442,992	
	17,400	2,486	7	0/6	–					
Rabbit	100,950	2,148	47	6/6	18(2), 48, 96(3)	1	14,667	4,799	44,829	1.371
	86,360	1,661	52	6/6	24, 42, 72, 96(2), 144	16	25,174	13,348	47,492	
	80,260	2,508	32	6/6	18, 48, 56, 80(2), 96	30	30,463	18,088	48,780	
	76,800	1,829	42	4/6	2, 42, 120, 144	50	37,683	27,839	51,008	
	62,400	1,950	32	6/6	18, 24, 60(2), 156(2)	84	56,407	44,706	71,171	
	55,950	3,730	15	6/6	72(2), 84, 108, 264, 408	99	96,816	50,168	186,839	
	52,080	3,472	15	6/6	84(2), 108(2), 192, 336					
	50,050	1,925	26	5/6	48, 72, 120(2), 264					
	34,070	3,786	9	0/6	–					
	21,660	3,094	7	1/6	216					
	4,216	1,054	4	0/6	–					
Rat	165,000	3,173	52	20/20	1(11), 18(3), 24(2), 48(4)	1	45,488	35,478	58,098	1.172
						16	69,025	61,192	77,861	
	123,200	1,987	62	16/20	18(6), 48(4), 56, 84, 120(2), 240, 408	30	80,025	73,293	87,376	
						50	94,378	87,323	102,003	
	100,950	2,148	47	10/20	18(2), 48(6), 72, 240	84	129,043	112,072	148,584	
	86,360	1,661	52	7/20	18(2), 24, 42(2), 50, 168	99	196,191	149,634	257,233	
	79,250	991	80	7/20	18(3), 24(3), 42					
	76,800	1,829	42	4/20	26(3), 42					
	62,400	1,950	32	3/20	48, 56(2)					
	21,660	3,094	7	0/20	–					

Table A-IV. Continued

Species	Ct mg min/cu m	Concentration mg/cu m	Exposure Time min	Mortality	Times to Death* hour	Bliss Statistical Analysis				
						P	Ei(P)	Lower Limit	Upper Limit	Std Error of Slope
Guinea Pig	165,000	3,173	52	20/20	1(5), 24(12), 48, 120, 156	1	20,847	7,075	61,426	.623
	134,500	2,587	52	18/20	1(8), 19(3), 43(4), 72(2), 132	16	40,176	25,051	64,432	
						30	50,645	38,831	66,054	
	86,360	1,661	52	17/20	1(5), 24, 42(8), 72, 168	50	65,573	58,834	73,084	
	76,800	1,829	42	14/20	1(8), 42(5), 48	84	107,026	66,753	171,595	
	67,300	1,819	37	11/20	1(4), 24, 120(5), 240	99	206,759	70,020	607,579	
	62,400	1,950	32	9/20	1(3), 42(3), 56(3)					
	50,050	1,925	26	4/20	4, 26, 264, 456					
	34,070	3,786	9	0/20	–					
	33,760	1,688	20	1/20	48					
	12,975	2,595	5	1/20	1					
	3,384	1,128	3	0/20	–					
All Non-Rodents						1	3,003	685	13,158	.525
						16	12,361	5,966	25,610	
						30	20,369	12,661	32,771	
						50	35,559	27,940	45,256	
						84	102,293	62,879	166,414	
						99	421,099	123,941	1,130,719	
All Rodents						1	23,207	9,208	58,488	.467
						16	46,821	31,256	70,139	
						30	59,985	47,854	75,890	
						50	79,080	72,796	85,906	
						84	133,564	89,771	198,720	
						99	269,472	107,666	674,446	
All Species Combined						1	6,996	2,962	16,529	.231
						16	24,096	16,320	35,577	
						30	37,284	29,565	47,019	
						50	60,674	54,439	67,623	
						84	152,775	106,994	218,146	
						99	526,171	230,573	1,200,729	

*14 day observation period.
**Number in parentheses represents number of animal deaths on given day.

Table A-V. Inhalation Toxicity of CS2 in Guinea Pigs, Rats, Monkeys and Dogs

Species	Concentration mg/cu m	Exposure Time min	Ct mg min/cu m	Mortality	Times to Death hour	Bliss Statistical Analysis				
						P	ED(P)	Lower Limit	Upper Limit	Std Error of Slope
Monkey	2,760	12	33,120	0/6	–	1	19,728	6,485	60,018	4.05
	1,700	25	42,500	2/6	1,312	16	42,093	23,221	76,303	
	2,150	43	92,450	3/6	8(2)*, 144	30	55,002	35,132	86,113	
	1,910	70	133,700	5/6	1, 2(3), 144	50	74,127	51,802	106,073	
	3,420	52	177,840	6/6	1(5), 2	84	150,540	77,291	220,475	
						99	278,528	99,832	777,087	
Dogs	3,160	18	56,880	0/6	–	1	52,238	36,231	75,318	17.95
	2,400	28	67,200	3/6	8(2), 336	16	61,969	51,599	74,422	
	3,780	20	75,600	4/6	16 (4)	30	66,820	57,986	74,713	
	3,000	27	81,000	5/6	2(2), 8(2), 24	50	70,399	64,515	76,821	
	2,750	38	104,500	6/6	5(4), 10, 72	84	79,978	68,584	93,264	
						99	94,876	68,024	132,326	
Rats	1,060	20	21,200	0/20	–	1	29,624	22,232	39,473	6.49
	1,135	30	34,050	1/20	48	16	47,504	41,473	54,412	
	1,380	35	48,300	2/20	24,30	30	56,120	50,003	62,986	
	873	60	52,380	3/20	24(2), 48	50	67,588	59,022	77,398	
	1,023	60	61,380	11/20	<24(2), 48(7), 192, 384	84	96,165	75,417	122,621	
	2,370	45			1(8), 8, 48(5), 72(2), 120	99	154,206	101,197	234,983	
	1,060	20	127,850	19/20	144(2)					
Guinea Pigs	1,060	20	21,200	0/20	–	1	31,693	18,835	53,327	12.25
	1,135	30	34,050	2/20	36,144	16	40,711	31,684	52,310	
	1,380	35	48,300	3/20	18, 30, 48	30	44,473	37,931	52,145	
	873	60	52,380	14/20	18, 20, 48(3), 72(3), 96	50	49,082	45,556	52,881	
					120(4), 144	84	59,174	49,475	70,776	
	1,023	60	61,380	20/20	<24(2), 48(5), 72(2),	99	76,013	48,671	118,714	
				–	144(6), 192(3), 288(2)					
Rat and Guinea Pig Data Combined						1	26,843	16,411	43,906	7.15
						16	41,224	34,462	49,313	
						30	47,965	43,976	52,315	
						50	56,792	51,221	62,969	
						84	78,238	56,586	108,175	
						99	120,154	63,209	228,400	
Dog and Monkey Data Combined						1	24,442	12,801	46,669	5.13
						16	44,422	31,729	62,991	
						30	54,850	42,983	69,993	
						50	69,397	57,932	83,130	
						84	108,414	82,022	143,296	
						99	197,034	110,406	351,631	
All Species Combined						1	23,502	16,259	33,972	5.64
						16	40,463	34,829	47,009	
						30	49,017	44,803	53,628	
						50	60,710	55,590	66,301	
						84	91,087	72,393	114,609	
						99	156,825	99,545	247,063	

*Number in parenthesis indicates number of animals.

Table A-VI. Intragastric Toxicity of CS and CS2 in Rats and Rabbits

Compound	Species	Dose mg/kg	Mortality	Bliss Statistical Analysis				
				P	ED(P)	Lower Limit	Upper Limit	Std Error of Slope
CS	Rabbit	50	0/6	1	268	123	586	13.3
		100	0/6	16	358	231	494	
		350	2/6	30	366	286	468	
		400	2/6	50	401	354	453	
		450	4/6	84	476	364	622	
		500	6/6	99	599	308	1162	
		1000	6/6					
	Rat	300	0/6	1	340	77	750	4.3
		600	2/6	16	486	265	891	
		900	4/6	30	623	400	970	
		1200	4/6	50	822	599	1127	
		1500	5/6	84	1390	893	2162	
		2400	6/6	99	2808	1092	7224	
CS2	Rabbit	50	0/6	1	74	14	383	3.3
		100	1/6	16	189	85	419	
		250	0/6	30	262	151	454	
		400	2/6	50	379	251	571	
		500	5/6	84	762	374	1668	
		1000	6/6	99	1940	381	9868	
	Rat	300	0/6	1	649	239	1766	12.9
		600	0/6	16	824	498	1364	
		900	2/6	30	896	639	1259	
		1200	5/6	50	985	811	1196	
		1500	6/6	84	1176	839	1649	
		1800	6/6	99	1293	657	3393	

Table A-VII. Intragastric Effects of CS and CS2 in Rabbits and Rats*

Compound	Species	Animal No.	Dose mg/kg	Observations	Mortality
CS	Rabbit	1-6	50	No noticeable signs for 30 days	0/6
		7-12	100	No noticeable signs for 30 days	0/6
		13-16	350	No noticeable signs for 30 days	
		17-18		Dec activity in 6 hours; died in less than 20 hours (ON)**	2/6
		19-22	400	No noticeable signs for 30 days	
		23-24		Dec activity at 6 hours; died in less than 20 hours (ON)	2/6
		25	450	Died in less than 20 hours (ON)	
		26		No noticeable signs for 30 days	
		27-28		Died in less than 19 hours (ON)	
		29		No noticeable signs for 30 days	
		30		Died in less than 19 hours (ON)	4/6
		31	500	1 hour, dec activity; 2 hours, diarrhea; 3 hours, down; 4 hours, dead	
		32		Died in less than 20 hours (ON)	
		33		30 min, dec activity; 3 hours, down; 4 hours, dead	
		34		Died in less than 20 hours (ON)	
		35		Inc resp in 4 hours, died in 6 hours	
		36		Died in less than 20 hours (ON)	6/6
		37-42	1000	All animals died in less than 20 hours (ON)	6/6
	Rat	1-6	300	No noticeable signs for 30 days	0/6
		7	600	Died in less than 48 hours	
		8-9		No noticeable signs for 30 days	
		10		Died in less than 72 hours	
		11-12		No noticeable signs for 30 days	2/6
		19-21	400	No noticeable signs for 30 days	
		22		40 min, inc breathing, unable to right self; 1 hour, dead	
		23		No noticeable signs for 30 days	
		24		1 hour, inc breathing, unable to right self; 2 hours, dead	2/6

* (CS – aqueous solution of 250 mg/cc in rabbits 200 mg/cc in rats. CS2 – an aqueous suspension with 20% EtoH)
** Overnight

Table A-VII. Continued

Compound	Species	Animal No.	Dose mg/kg	Observations	Mortality
		25-27	500	Died within 48 hours (ON)	
		28		1 hour, inc breathing; unable to right self; 1.5 hours, dead	
		29		No noticeable signs for day 1, 2, 3, 4, 5, 6, 7, 8, 9; died on 10th day	
		30		No noticeable signs for 30 days	5/6
		31-35	1000	1 hour, unable to right self; died overnight	
		36		1 hour, unable to right self; died in 90 min	6/6
CS2	Rat	1-6	300	No noticeable signs for 30 days	0/6
		7-12		No noticeable signs for 30 days	0/6
		13-16	900	No noticeable signs for 30 days	
		17-18		Died overnight	2/6
		19-23	1200	Died overnight	
		24		1 hour, inc breathing; no noticeable sig s 7 days up to 30 days	5/6
		25-28	1500	Died overnight	
		29-30		Immed inc breathing, immobile; died in 3 hours	6/6
		31-33	1800	Died overnight	
		34		Died in less than 48 hours (ON)	
		35-36		Died within 2 hours	6/6
		13-16	900	Died overnight	
		17-18		No noticeable signs for 30 days	4/6
		19	1200	No noticeable signs on day 1; dec activity on day 2; died on day 3 (ON)	
		20-21		No noticeable signs for 30 days	
		22		No noticeable signs on 1st day up to 15th day; died on 16th day	
		23		No noticeable signs; died in 36 hours	
		24		No noticeable signs on 1st day; 2nd day, inc breathing; died on 16th day	4/6
		25	1500	1 hour, inc breathing; 90 min, down; 2.5 hours, dead	
		26		1 hour, inc breathing, 50 min, down, 1.5 hours, dead	
		27		1 hour, inc breathing followed b / down; 1.6 hours, dead	
		28		30 min, inc breathing, 120 min, down; 3.5 hours, dead	
		29		1 hour, inc breathing, 85 min, down; 2 hours, dead	
		30		1 hour, dec activity; 48 hours, no noticeable signs to 30 days	5/6

Table A-VII. Continued

Compound	Species	Animal No.	Dose mg/kg	Observations	Mortality
		31	2400	30 min, shallow breathing, dec activity; 36 hours, dead	
		32		30 min, shallow breathing, dec activity; 48 hours, dead	
		33		30 min, shallow breathing, dec activity; 288 hours, dead	
		34		30 min, shallow breathing, dec activity; 36 hours, dead	
		35-36		30 min, shallow breathing, dec activity; 48 hours, dead	6/6
CS2	Rabbit	1-6	50	No noticeable signs for 30 days	0/6
		7-10	100	No noticeable signs for 30 days	
		11		Died in less than 24 hours	
		12		No noticeable signs for 30 days	1/6
		13-18	250	No noticeable signs for 30 days	0/6

Table A-VIII. CS Feeding Studies in Rabbits and Rats

Species	Dosage Level* mg/kg/day	Actual Average Daily Food Consumption (30-day period)		Actual Average Daily Dose of CS (30-day period)
		grams	percent of ration	mg/kg
Rabbit	1	101	67	0.67
	10	111	74	7.4
	50	105	70	35.0
	100	100	67	67.0
	250	97	64	160.0
	500	62	41	205.0
	Control	105	70	0
Rat	1	14	56	0.56
	10	13	52	5.2
	50	13	52	26.0
	100	13	52	52.0
	250	13	52	130.0
	500	12	48	240.0
	Control	15	60	0

* Assuming 100 percent consumption of daily ration.

Table A-IX. Daily Food Consumption and Body Weight Changes in Rats Eating Laboratory Chow Contaminated with CS

Daily Dose (mg/kg)* No. of Animals	1 4	10 4	50 4	100 4	250 4	500 4	Controls 2
Day	Average Daily Food Consumption Per Rat (Grams)						
1	8	7	13	8	8	8	16
2	14	12	13	16	12	2	12
3	17	19	14	19	16	16	21
4	17	13	17	20	13	10	11
5	19	19	17	18	–	14	20
6	16	16	15	13	17	12	13
7	13	13	15	13	8	12	16
8	12	14	14	15	15	14	14
9	12	11	12	10	16	13	12
10	23	13	13	15	8	17	13
11	16	12	13	15	14	13	16
12	15	15	14	12	9	11	15
13	15	15	15	10	12	13	14
14	12	14	13	13	14	13	18
15	14	12	11	13	12	12	17
16	14	12	13	12	13	13	16
17	13	12	16	15	12	13	17
18	14	11	11	11	13	14	16
19	13	12	11	10	12	15	14
20	13	15	13	15	15	9	14
21	13	10	13	12	12	11	13
22	14	12	11	13	14	16	15
23	11	7	13	11	13	16	14
24	11	10	13	11	13	12	15
25	14	11	13	14	13	13	17
26	12	13	14	14	13	13	13
27	13	13	13	13	12	13	15
28	13	13	12	11	16	12	14
29	13	14	13	14	13	11	15
30	15	13	14	13	9	15	11
Average Body Wt (kg) on Day:							
1	0.203	0.208	0.209	0.209	0.156	0.159	0.195
14	0.210	0.222	0.218	0.218	0.167	0.160	0.213
21	0.228	0.228	0.228	0.225	0.183	0.180	0.222

* Assuming that each rat would eat 25 grams of food per day.

Table A-X. Daily Food Consumption and Body Weight Changes in Rabbits Eating Laboratory Chow Contaminated with CS

Daily Dose (mg/kg)* No. of Animals	1 4	10 4	50 4	100 4	250 4	500 4	Controls 2
Day	Average Daily Food Consumption Per Rabbits (Grams)						
1	94	75	81	37	51	16	103
2	103	107	75	61	83	67	98
3	106	114	94	69	105	30	114
4	88	82	80	61	73	20	89
5	90	88	102	50	96	33	89
6	84	85	81	70	121	58	74
7	86	82	81	81	95	43	92
8	128	124	124	113	126	54	122
9	98	99	105	99	124	61	68
10	116	119	113	115	112	78	142
11	126	133	127	131	77	44	145
12	115	127	108	102	75	61	94
13	117	129	116	107	112	76	102
14	117	135	128	124	99	50	108
15	119	116	131	123	118	115	104
16	125	127	140	122	126	73	110
17	112	113	121	122	130	51**	121
18	94	107	100	110	115	102	115
19	78	88	69	80	115	94	103
20	90	117	108	108	78	68	131
21	98	115	104	113	79	75	127
22	71	97	97	93	78	96	94
23	96	114	78	113	94	85	137
24	93	125	115	128	75	47	117
25	99	128	113	123	101	52	123
26	100	129	120	107	66	44	120
27	108	140	121	136	90	54	127
28	90	83	98	110	99	56	114
29	83	102	96	90	88	43	106
30	103	126	125	110	106	102	115
Average Body Wt (kg) on Day:							
1	2.0	2.1	2.1	2.1	2.7	2.5	2.4
14	2.3	2.5	2.5	2.4	2.7	2.4	2.6
30	2.3	2.6	2.5	2.6	2.7	2.4	2.7

* Assuming that each rabbit would eat 150 grams of food per day.
** One death.

Table A-XI. Inhalation Toxicity of Pure CN and A Bliss Statistical Analysis of the Data for Each Experiment in Each Species of Animals (1918 - 1959, inclusive)

Source of/and Pertinent Information	Species	Ct mg min/m³ a	Conen mg/m³ a	Exposure Time min	Observation Period	Mortality Fraction	Times to Death	Statistical Analysis P	LD(P)	Lower Limit	Upper Limit
Source: Aerosol Branch Dir/Med/Bech,CWSL, EA, MD	Rat	2220	148	15	14 days	2/10	14 days	1	837	1.7	497373
		2970	198	15	"	1/10	2 days	16	3810	2033	7141
		4178	279	15	"	0/10	-	30	6500	2085	20368
Dates: 14-19 August 1958		4668	311	15	"	1/10	10 days	50	11819	423	330383
		4985	332	15	"	6/10	1(3)*,3(3) days	84	36664	22	61516680
Investigators: T.A. Ballard		5145	343	15	"	0/10	-	99	166978	0.4	66742250000
J.T. Weimer		5255	350	15	"	0/10	-				
		7409	494	15		6/10	5 (6) days		SLOPE - 2.0		
Method of Dispersion: Nilon Spray											
Analytical: UV 268 millimicron in CHCl											
Source: As above	Rat	645	43	15	14 days	0/6	-	1	431	193	963
		696	46	15	"	1/6	Not recorded	16	668	485	920
Dates: 16-17 September 1958		771	51	15	"	4/6	< 1 day	30	780	635	959
		990	66	15	"	2/6	Not recorded	50	927	799	1076
Investigators: As above		1771	354	5	"	6/6	6 hrs	84	1286	730	2267
								99	1994	680	5849
Method of Dispersion: Pneumatic Dust									SLOPE - 6.99		
Analytical: UV 268 millimicron in CHCl											
Source: As above	Rat	2020	404	5	14 days	0/10	Not recorded	1	1400	399	5482
		3670	367	10	"	0/10	" "	16	3824	2057	7109
Dates: July 1959		6290	370	17	"	7/10	" "	30	5347	3587	7969
		7440	496	15	"	4/10	" "	50	7770	6101	9895
Investigator: As above		9440	472	20	"	7/10	" "	84	15788	9103	27390
		12626	702	18	"	5/10	" "	99	40799	11868	140258
Method of Dispersion: Aerosol Spray		13240	441	30	"	10/10	" "				
		29776	851	35	"	9/10	" "		SLOPE - 3.23		
Analytical: Colorimetric											

* Number in parenthesis indicates number of animal mortalities at given time; otherwise only a single mortality occurred at given time.

Table A-XI. Continued

Source of/and Pertinent Information	Species	Ct mg min/cu m	Conc mg/cu m	Exposure Time min	Observation Period	Mortality Fraction	Time to Death	P	[illegible](P)	[illegible] Limits	[illegible]
Source: Aerosol Branch Date: July-August [illegible] Investigators: T.A. [illegible] J.T. [illegible] Method of Dispersion: Molten 150°-180°C sprayed from Jet Analytical: (1) UV at 280 millimicrons in [illegible] (2) UV at 268 millimicrons in $CHCl_3$	Mouse	2040	204	10	14 days	20/24	28 (28)[?] days	1	1670659800		
		2090	209	10	"	8/12	2, 12 (T)-days	16	229018		
		2124	18	120	"	0/12		30	9915		
		2749	15	180	"	0/12		[illegible]	[illegible]		
		2928	18	160	"	1/12	6 days	[illegible]	0.4		
		4400	440	10	"	1/12	2 days	99	0		
		5460	156	35	"	7/12	3(2), T(2), 8, 9, 13 days		SLOPE - 0.3		
		7040	704	10	"	3/12	1, 12(2) days				
		10641	355	30	"	1/12	1 day				
		15048	84	180	"	1/12	11 days				
		34090	974	35	"	7/12	11 days				
Source: As above Dates and Investigators: As above Method of Dispersion: Pneumatic Burst Analytical: UV at 268 millimicrons $CHCl_3$	Mouse	399	27	15	"	3/10	1 (3) days	1	10	0	[illegible]
		576	38	15	"	4/10	1, 3(3) days	16	189	0.9	4112[?]
		951	63	15	"	7/10	Not recorded	30	[illegible]	67	4118[?]
		1110	370	30	"	4/10	1(2), 2(3) days	[illegible]	1622	[illegible]	[illegible]
		1148	77	15	"	0/10	-	[illegible]	[illegible]	[illegible]	[illegible]
		1268	85	15	"	0/10	-	99	265380	[illegible]	-
		1437	144	10	"	7/10	1 (T) day		SLOPE - 1.1		
		2199	146	15	"	8/10	Not recorded				
Source: As above Date: 14 November 1958 Investigators: As above Method of Dispersion: As above Analytical: Colorimetric ([illegible])	Mouse	438	89	15	"	2/10	Not recorded	1	565	800	399
		303	20	15	"	6/20	"	16	374	448	313
		195	13	15	"	18/20	"	30	[illegible]	372	[illegible]
								[illegible]	[illegible]	[illegible]	[illegible]
								[illegible]	[illegible]	[illegible]	[illegible]
								99	134	196	92
									SLOPE - 1.56		
Source: [illegible] A.J. [illegible] [illegible] 97, [illegible] (2) Toxicity [illegible] in Mice Date: 16 March 1948[?] Method of Dispersion or Analytical Method not specified.	Mouse	1000	100	10	48 hr	0/2	-	Not applicable			
		1900	190	10	"	0/4					
		7300	730	10	"	0/4					
		8900	890	10	"	0/4					

Appendix

Table A-XI. Continued

Source of/and Pertinent Information	Species	Ct mg min/cu m	Concn mg/cu m	Exposure Time min	Observation Period	Mortality Fraction	Time to Death	P	ED(P)	Lower Limit	Upper Limit
								Statistical Analysis			
Source: Aerosol Branch	Guinea Pig	793	53	15	14 days	0/6	-	Not applicable			
Date: 28 November 1958		1486	97	15	"	0/6	-				
Investigators: T.A. Ballard, J.T. Weimer		1600	107	15	"	0/6	-				
Method of Dispersion: Pneumatic Dust		1904	127	15	"	0/6	-				
Analytical: Colorimetric (m-dinitrobenzene)		1995	133	15	"	0/6	-				
		2303	154	15	"	0/6	-				
Source: Aerosol Branch	Guinea Pig	1650	330	5	14 days	2/10	Not recorded	1	505	182	[illegible]
Date: July 1959		1890	270	7	"	3/10	" "	16	1520	845	[illegible]
Investigators: As above		4950	330	15	"	5/10	" "	30	2242	1417	[illegible]
Method of Dispersion: Acetone Spray		9450	315	30	"	10/10	" "	50	3452	[illegible]	[illegible]
Analytical: Colorimetric		10310	515	20	"	8/10	" "	84	7673	[illegible]	[illegible]
		15189	337	45	"	10/10	" "	99	23689	10761	[illegible]
									SLOPE - 2.78		
Source: Gavin, Crandall, Marlow, MN XXVI-91	Dog	1800	60	30	9-10 days	0/2	-	1	[illegible]	[illegible]	[illegible]
Date: 6 July 1918		1920	64	30	"	0/2	-	16	[illegible]	[illegible]	[illegible]
Method of Dispersion: Thermal dispersion dissolved in benzol		5400	180	30	"	2/2	53 hr, 64 hr	30	2979	698	[illegible]
Analytical Concentration		7200	240	30	"	4/4	29 hr, 49.5 hr	50	[illegible]	[illegible]	[illegible]
		11100	370	30	"	2/2	43 hr, 48 hr	84	[illegible]	[illegible]	[illegible]
		11400	380	30	"	0/2	-	99	27571	[illegible]	[illegible]
		17310	577	30	"	2/2	21 hr (2)				
		18300	610	30	"	2/2	1 hr, 26 hr		SLOPE - 2.94		
		21900	730	30	"	2/2	18 hr (2)				
		32700	1090	30	"	2/2	20 min, 25 min				
		34200	1140	30	"	2/2	15 min, 19 min				
		39900	1330	30	"	2/2	15 min, 24 min				
Source: C.A. Ransom, F.B. Bogert MN XXVI-91	Dog	4500	150	30	Not recorded	1/2	11 days	1	1045	64	[illegible]
Date: 22 August 1918		5700	190	30	"	1/2	48 hrs	16	3566	[illegible]	[illegible]
Method of Dispersion: CN heated to 155 °C		6300	210	30	"	0/2	-	30	[illegible]	[illegible]	[illegible]
Analytical Concentration		7800	260	30	"	0/2	-	50	[illegible]	[illegible]	[illegible]
		8100	270	30	"	1/2	10 days	84	[illegible]	[illegible]	[illegible]
		8400	280	30	"	2/4	48 hr, 7 days	99	76031	4741	[illegible]
		9600	320	30	"	1/2	24 hr				
		9750	325	30	"	1/2	36 hr				
		10200	340	30	"	1/2	48 hr				
		10350	345	30	"	2/2	24 hr, 36 hr				
		11400	380	30	"	0/2	-				
		12300	410	30	"	2/2	48 hr, 6 days				
		12900	430	30	"	1/2	3 days				
		14100	470	30	"	2/2	48 hr (2)				

Appendix

Table A-XI. Continued

Source of/and Pertinent Information	Species	Ct	Concn	Exposure Time	Observation Period	Mortality Fraction	Times to Death	P	ED(P)	Lower Limit	Upper Limit
								Statistical Analysis			
		mg min/cu m	mg/cu m	min							
Source: R.P. Gilbert	Dog	900	30*	30	Not recorded	0/1	-		Not applicable		
R.H. Johnson, EM XXII-76		3300	110*	30	"	1/1	24 hrs				
Date: 25 June 1918		5100	170*	30	"	0/1	-				
Method of Dispersion: A cohole*		5100	170*	30	"	0/1	-				
and Heat Vaporization**		2400	80**	30	"	0/1	-				
Analytical Concentration		1500	50**	30	"	0/1	-				
ALL RODENTS - 1918 - 1959								1	.0	.0	XXXX
								16	.26	.0	[illegible]
								30	139.70	.0	1998438
								50	194539.	.4	60116690000
								84	91518861000	.0	.00
								99	XXXXXXXXX	.0	.00
									SLOPE - .106124		
NOTE: Non-rodents; Dogs only								1	950	213	4828
								16	2988	1390	6423
								30	4479	2630	7625
								50	7033	4993	9907
								84	16554	9583	20998
								99	52085	14941	181577
									SLOPE - 2.68		
ALL SPECIES COMBINED, 1918-1959								1	.02	.00	68100
								16	53.02	.32	8632
								30	928.22	191.74	4494
								50	22618	1630	313920
								84	9648027	361	257988350000
								99	320346630000	45	XXXXXXXXX

Appendix

Table A-XII. Inhalation Toxicity of CN (10% in Acetone – Wt/Vol) in Seven Animal Species (30-Day Observation)

Species	Ct	Concentration	Exposure time	Mortality	Time to death*	Statistical analysis				
						P	ED50	Lower limit	Upper limit	Standard error of slope
	mg min/cu m	mg/cu m	min		hr					
Monkey	29,790	259	115	5/6	18,24,96(3)	1	1,380	15	130,944	0.89
	18,100	201	90	2/6	24,120	16	5,916	1,121	31,223	
	12,200	203	60	2/6	18,240	30	9,890	4,549	21,499	
	6,300	210	30	1/6	68	50	17,542	7,338	41,939	
	4,520	226	20	1/6	216	84	52,017	2,817	960,503	
						99	222,994	647	76,902,480	
Dog	17,370	217	80	6/6	18(6)	1	4,410	2,657	7,318	8.37
	6,300	210	30	5/6	18(3),20,44	16	5,073	4,066	6,330	
	5,300	147	36	2/6	24,72	30	5,331	4,658	6,101	
	4,520	226	20	0/6		50	5,633	4,097	6,227	
	2,700	208	13	0/6		84	6,255	4,798	8,154	
						99	7,196	4,137	2,516	
Swine	17,370	217	80	6/6	1,18(4),44	1	1,717	80	36,520	2.48
	7,640	191	40	5/6	16(3),17,72	16	2,937	653	13,202	
	5,700	190	30	6/6	18,48,90,162,408(2)	30	3,549	1,355	9,295	
	4,550	152	30	2/6	335,600	50	4,384	2,937	5,545	
	3,550	197	18	2/6	18,288	84	6,545	2,687	15,941	
						99	11,193	983	127,416	
Goat	17,370	217	80	6/6	18(4),120(2)	1	305	3.2	28,715	1.509
	12,210	222	55	5/6	19(3),72,96	16	1,008	70.1	14,502	
	7,640	191	40	2/6	216(3),218,264,336	30	1,537	210.2	11,245	
	5,700	190	30	6/6	115,168,264,272,408(2)	50	2,462	738.5	8,211	
	3,550	197	18	3/6	120,264,268	84	6,015	3,209	11,271	
						99	19,890	3,411	115,964	
Rabbit	31,035	282	110	6/6	2(2),18(4)	1	2,579	1,163	5,718	2.009
	20,160	310	65	6/6	18(6)	16	4,118	2,714	6,250	
	11,200	249	45	6/6	19(6)	30	4,859	3,609	6,540	
	10,160	203	50	6/6	18,24,28,72,96(2)	50	5,842	4,782	7,138	
	7,645	191	40	4/6	72,216,384(2)	84	8,287	6,185	11,105	
	6,300	210	30	3/6	18,48,72	99	13,236	6,882	25,456	
	5,300	147	36	2/6	336(2)					
	4,375	175	25	2/6	144,216					
Rat	31,035	282	110	20/20	18(20)	1	2,939	1,613	5,357	0.70
	20,160	310	65	19/20	18(18),36(1)	16	5,769	4,389	7,584	
	11,200	249	45	16/20	19(8),38(5),67(1),70(1), 168(1)	30	7,320	6,135	8,735	
						50	9,347	8,353	10,910	
	10,160	203	50	8/20	18(4),172(2),96(1), 120(1)	84	15,797	11,617	21,481	
						99	31,008	16,392	58,657	
	7,645	191	40	2/20	18(1),72(1)					
	6,300	210	30	5/20	20(2),44(1),68(2)					
	4,375	175	25	3/20	240(3)					

Table A-XII. Continued

Species	Ct	Concentration	Exposure time	Mortality	Time to death*	Statistical analysis				
						P	ED50	Lower limit	Upper limit	Standard error of slope
	mg min/cu m	mg/cu m	min		hr					
Guinea pig	34,910	218	160	20/20	24(2),28(2),48(5) 72(2),96(3),98(1), 120(4),144(1)	1	3,743	1,883	7,445	0.537
						16	7,754	5,302	11,339	
						30	10,026	7,581	13,260	
						50	13,355	11,090	16,082	
	31,035	282	110	19/20	2(2),18(10),36(4), 42(1),60(1),91(1)	84	23,001	18,834	28,091	
						99	47,637	29,552	76,790	
	29,235	217	135	19/20	48(2),72(3),96(2), 120(4),144(6),126(1), 216(1)					
	24,225	211	115	20/20	72(1),96(1),122(7), 124(1),158(8),216(2)					
	20,160	310	65	12/20	36(1),54(1),91(1), 94(1),384(8)					
	11,200	249	45	3/20	168(3)					
	6,300	210	30	3/20	144(2),456					
	3,700	148	25	1/20	288					
All rodents (rat and guinea pig)	-	-	-	-	-	1	2,764	1,712	4,463	0.352
						16	6,131	4,826	7,790	
						30	8,123	6,885	9,583	
						50	11,116	9,925	12,449	
						84	20,152	16,488	24,629	
						99	44,701	28,919	69,095	
Nonrodent	-	-	-	-	-	1	617	130	2,933	0.442
						16	2,166	997	4,706	
						30	3,374	2,027	5,617	
						50	5,533	4,293	7,131	
						84	14,137	8,711	22,942	
						99	49,645	14,174	173,882	
All species combined	-	-	-	-	-	1	1,268	655	2,452	-
						16	3,752	2,723	5,168	
						30	5,502	4,466	6,779	
						50	8,435	7,507	9,478	
						84	18,965	14,818	24,271	
						99	56,125	31,389	100,354	

* Number in parenthesis indicates number of animals which died at the given times.

Table A-XIII. CN Acute Inhalation Toxicity (Commercial Grenade)

Species	Ct	Concentration	Exposure time	Mortality	Time to death*	Statistical analysis						
						P	ED(P)	Lower limit	Upper limit	Probit Y (-)	Log X (+)	Standard error
	mg min/cu m	mg/cu m	min		hr							
Monkey (Macaca Rhesus)	36,100	4,011	9	6/6	14 (6)	1	6,173.4	1,278.0	29,819.9	31.7	9.07	3.91
	12,550	2,092	6	4/6	21 (4)	16	8,675.5	5,363.4	13,974.9			
	8,470	1,694	5	1/6	552 (1)	30	9,755.2	8,140.3	11,690.4			
	6,189	1,547	4	0/6	-	50	11,144.7	10,566.3	11,754.6			
	2,700	675	4	0/6	-	84	14,346.3	5,225.3	39,388.2			
						99	20,119.2	2,511.2	161,188.3			
Dog	43,392	2,669	14	6/6	19 (5),48 (1)	1	3,056.4	620.0	15,066.8	8.39	3.18	0.95
	36,100	4,011	9	4/6	2 (1),14 (2),98 (1)	16	8,029.1	3,526.5	18,280.5			
	12,550	2,092	6	4/6	21(1),48(1),54(1),78(1)	30	11,290.9	6,172.9	20,652.3			
	8,470	1,694	5	0/6	-	50	16,515.4	10,225.3	28,675.8			
	2,700	675	4	0/6	-	84	33,971.1	15,727.3	73,377.9			
						99	89,241.1	19,275.0	413,175.3			
Goat	26,139	2,354	9	6/6	18 (6)	1	3,776.1	1,090.7	12,073.1	11.1	3.85	1.17
	25,086	2,826	8	3/6	16 (2),48 (1)	16	8,367.2	4,508.1	15,529.9			
	17,475	2,496	7	5/6	18 (1),336 (3),624 (1)	30	11,080.2	7,196.6	17,059.6			
	14,126	2,354	6	2/6	48 (1),114 (1)	50	15,156.7	11,073.1	20,746.2			
	7,700	1,540	5	1/6	72 (1)	84	27,455.5	15,700.9	48,010.3			
	4,700	1,175	4	0/6	-	99	60,837.1	18,807.8	196,788.6			
Swine	26,139	2,354	9	6/6	18(6)	1	490.0	5.2	46,234.2	3.30	2.22	0.75
	17,475	2,496	7	6/6	18(5),24(1)	16	1,952.8	210.3	18,135.6			
	14,126	2,354	6	2/6	19(1),144(1)	30	3,181.2	763.8	13,249.1			
	7,700	1,540	5	5/6	17(3),24(1),312(1)	50	5,482.9	2,973.6	10,109.9			
	6,189	1,547	4	5/6	22(1),48(3),72(1)	84	15,394.9	3,900.7	60,759.6			
	4,700	1,175	4	3/6	72(1),106(1),587(1)	99	61,349.9	1,563.6	2,407,215.2			
	4,080	1,240	3	3/6	18(1),72(1),163(1)							
	3,800	950	4	0/6								
Rabbit	55,650	3,975	14	6/6	2(2),4(3),18(1)	1	3,282.8	373.6	28,844.3	9.33	3.41	1.16
	36,100	4,011	9	6/6	24(1),38(1),48(1)	16	8,063.1	2,356.3	27,591.2			
					65(1),89(1),168(1)	30	11,072.7	4,443.2	27,593.4			
	32,866	2,892	10	5/6	3(4),24(1)	50	15,773.0	8,695.5	28,611.2			
	25,086	2,826	8	3/6	18(3)	84	30,855.2	18,637.2	51,082.9			
	12,550	2,092	6	3/6	168(1),192(1),240(1)	99	75,784.4	19,980.5	287,443.8			
	2,700	675	4	0/6	-							
Rat	55,650	3,975	14	20/20	4(6),6(3),18(10),	1	8,332.9	5,135.8	13,520.3	17.7	5.20	0.93
					20(1)	16	15,024.3	11,416.0	19,772.9			
	36,100	4,011	9	18/20	14(4),24(5),38(6)	30	18,499.3	14,998.2	22,817.6			
					52(3)	50	23,332.2	19,974.5	27,254.2			
	32,886	2,892	10	16/20	24(11),48(4),62(1)	84	36,234.0	30,437.3	43,134.6			
	25,086	2,826	8	7/20	16(2),48(5)	99	65,330.0	45,625.0	93,545.4			
	12,550	2,092	6	3/20	45(3)							
	2,700	675	4	0/20	-							

*Number in parenthesis indicates number of animals that died at the time indicated.

Table A-XIII. Continued

Species	Ct	Concentration	Exposure time	Mortality	Time to death*	Statistical analysis						
						P	ED(P)	Lower limit	Upper limit	Probit Y (-)	Log X (+)	Standard error
	mg min/cu m	mg/cu m	min		hr							
Guinea pig	55,650	3,975	14	20/20	2(5),4(3),6(3),18(8) 120(1)	1	972.2	110.9	8,515.8	3.12	1.93	0.34
						16	4,727.2	1,723.2	12,967.8			
	36,100	4,011	9	11/20	14(5),24(6)	30	8,261.3	4,431.2	15,401.9			
	25,086	2,826	8	12/20	16(5),48(6),593(1)	50	15,399.0	11,243.4	21,090.5			
	12,550	2,092	6	8/20	21(6),48(2)	84	50,162.7	21,100.2	119,254.9			
	8,470	1,694	5	11/20	24(3),48(4),96(2) 120(1),144(1)	99	243,907.2	32,346.9	1,839,150.2			
	2,700	675	4	0/20	-							
All rodents	-	-	-	-	-	1	2,160.5	677.6	6,888.5	5.79	2.54	0.31
	-	-	-	-	-	16	7,232.6	4,081.7	12,815.6			
	-	-	-	-	-	30	11,079.4	7,611.0	16,128.3			
	-	-	-	-	-	50	17,829.4	14,612.9	21,753.9			
	-	-	-	-	-	84	43,952.1	29,633.9	65,188.5			
						99	147,137.3	55,733.5	388,444.8			
All nonrodents	-	-	-	-	-	1	1,179.9	454.4	3,063.0	4.70	2.40	0.32
	-	-	-	-	-	16	4,231.9	2,666.6	6,715.8			
	-	-	-	-	-	30	6,642.3	4,875.8	9,048.9			
	-	-	-	-	-	50	10,983.0	8,920.3	13,522.7			
	-	-	-	-	-	84	28,504.4	18,811.1	43,192.7			
	-	-	-	-	-	99	102,230.8	41,445.3	252,166.6			
All species combined	-	-	-	-	-	1	1,302.3	603.2	2,811.5	4.31	2.24	0.20
	-	-	-	-	-	16	5,114.3	3,517.8	7,435.5			
	-	-	-	-	-	30	8,288.7	6,474.3	10,611.6			
	-	-	-	-	-	50	14,203.9	12,223.9	16,504.6			
	-	-	-	-	-	84	39,448.0	29,065.4	53,539.4			
	-	-	-	-	-	99	154,918.4	77,323.1	310,382.7			

* Number in parenthesis indicates number of animals that died at the time indicated.

Table A-XIV. Inhalation Toxicity of 10 Daily Exposures to CN (Commercial Grenade)

Day	Daily Ct	Cumulative Ct	Deaths		Daily Ct	Cumulative Ct	Deaths	Daily Ct	Cumulative Ct	Deaths		
			Guinea pig	Monkey			Dog			Guinea pig	Dog	Monkey
	mg min/cu m	mg min/cu m			mg min/cu m	mg min/cu m		mg min/cu m	mg min/cu m			
1	3,883	-	0/20	0/8	6,665	-	0/8	6,815	-	1/20	0/8	0/8
2	3,372	7,225	-	-	4,846	11,511	-	9,024	15,839	2/20	-	0/8
3	2,335	9,590	-	-	5,890	17,401	-	10,770	26,609	2/20	-	1/8
4	2,828	12,418	-	-	5,320	22,721	-	4,200	30,809	2/20	-	1/8
5	3,980	16,398	0/20	-	6,950	29,671	-	8,160	38,969	2/20	-	1/8
6	3,373	19,771	0/17 *	-	5,937	35,608	0/8	10,347	49,316	2/19	-	1/8
7	2,342	22,113	0/17	-	5,876	41,484	0/7 *	6,127	55,443	2/19 *	0/8	1/8
8	3,605	25,718	0/17	-	7,062	48,546	-	13,020	68,463	3/19	1/8	2/8
9	3,159	28,887	3/17	-	6,630	55,176	-	10,561	79,024	3/19	1/8	3/8
10	2,558	31,445	4/17	0/8	4,387	59,563	0/7	9,464	88,488	3/19	1/8	3/8
11	-	-	-	-	-	-	-	-	-	-	2/8	-
21	-	-	5/17	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	1/7	-	-	-	-	-
30	-	-	5/17	0/8	-	-	1/7	-	-	3/19	2/8	4/8

Acute Lethal Ct's for CN (No. 112 Commercial Grenade)

Monkey		Dog		Guinea pig	
P	mg min/cu m	P	mg min/cu m	P	mg min/cu m
1	6,173	1	3,056	1	972
16	8,676	16	8,029	16	4,727
30	9,755	30	11,291	30	8,261
50	11,145	50	16,515	50	15,399
84	14,346	84	33,971	84	50,163
99	20,119	99	89,241	99	243,907

* *Animals escaped.*

Table A-XV. Inhalation Toxicity Data for Pure DM and a Bliss Statistical Analysis of the Data for Each Experiment in Each Species of Animals (1918 – 1964, inclusive)

Source of/and Pertinent Information	Species	Ct	Concn	Exposure Time	Observation Period	Mortality Fraction	Times to Death	Statistical Analysis			
								P	ED(P)	Lower Limit	Upper Limit
		mg min/cu m	mg/cu m	min							
Source: Aerosol Branch, Dir/Med/Res Chem, E.A., Md. Date: June - Sept 1957 Investigator: T. A. Ballard Method of Dissemination: Dust	Rat	5400 13200 13250 15660 15950	181 440 442 522 532	30 30 30 30 30	2 wk.	2/6 6/6 6/6 6/6 6/6	Not recorded	1 16 30 50 84 99	3901 5342 6563 8783	3159 4137 4582 6590 5841 SLOPE - 13.2	4817 6234 6898 7419 7801 13209
Source: As above. Date: Jan 1954. Investigator: W.E. Hickman Method of Dissemination: Spray (in exotoxin)	Rat	2004 4136 5460 7363 8250 10800	167 188 182 199 165 108	12 22 30 37 50 100	2 wk.	0/10 1/10 4/10 4/10 6/10 7/10	Not recorded	1 16 30 50 84 99	2051 4346 5665 7614 13960 20263	815 2908 4377 6021 7165 9627 SLOPE - 4.0	5163 6493 7331 9270 29817 89006
Source: As above. Date: Sept 1963 Investigators: T.A. Ballard, W.E. Hickman Method of Dissemination: As above.	Rat	569 1122 2385 4069 5823 7423	Not Recorded	Not Recorded	2 wk.	0/10 8/10 8/10 6/10 10/10 10/10	Not recorded	1 16 30 50 84 99	133 487 770 1285 3394 12454	7 103 263 710 1610 1543 SLOPE - 2.4	2525 2894 2253 2326 7152 100698
Source: As above. Date: Aug 1963 Investigator: W.E. Hickman Method of Dissemination: As above.	Rat	300 1050 2255	Not Recorded	Not Recorded	2 wk.	0/10 2/10 4/10	Not recorded	1 16 30 50 84 99	290 1096 1623 2678 6923 24716	8 390 855 633 212 47 SLOPE - 2.4	10704 2750 3153 11706 xxxx xxxx

Table A-XV. Continued

Source of/and Pertinent Information	Species	Ct mg min/cu m	Concn mg/cu m	Exposure Time min	Observation Period	Mortality Fraction	Times to Death	Statistical Analysis P	ED(P)	Lower Limit	Upper Limit
Source: As above	Rat	2075	208	10	2 wk	0/10	Not recorded	1	Not applicable		
Date: April 1963		4155	208	20		0/10					
Investigator and Method of Dispersion: As above		6000	240	25		0/10					
		8096	245	33		0/10					
		10124	260	39		0/10					
		12242	395	31		0/10					
Source, Investigator and Method of Dispersion: As above	Rat	2832	354	8	2 wk	0/10	Not recorded	1	23704	15076	37270
Date: May 1963		7292	561	13		0/10		16	28271	27531	31120
		11720	617	19		0/10		30	31533	28316	35116
		21410	824	26		0/10		50	34264	29736	[illegible]
		27810	927	30		1/10		84	40109	29711	[illegible]
								99	49528	21764	112708
								SLOPE - 14.5			
Source, Investigator and Method of Dispersion: As above	Rat	612	Not Recorded	Not Recorded	2 wk	0/10	Not recorded	1	232	4	14068
Date: August 1963		792				2/10		16	891	234	[illegible]
		1808				0/18		30	1432	891	[illegible]
		2480				1/18		50	2431	987	[illegible]
		3560				10/10		84	6631	351	[illegible]
								99	25424	82	7973664
								SLOPE - 2.3			
Source: As above	Rat	2149	72	30	2 wk	5/6	Not recorded	1	61	0.0	[illegible]
Date: 1957		4388	293	15		3/6		16	376	0.3	[illegible]
Investigator: T.A. Ballard		6600	220	30		6/6		30	712	3	[illegible]
Method of Dispersion: Dust		6960	232	30		4/6		50	[illegible]	47	[illegible]
		10080	336	30		6/6		84	[illegible]	[illegible]	[illegible]
		18700	623	30		6/6		99	34465	318	3737671
		19200	640	30		6/6					
								SLOPE - 1.7			
Source: As above	Mouse	2004	120	20	? wk	0/10		1	1861	1193	2902
Date: February 1964		4136	188	22		1/10	15 to 20 min.	16	3431	2762	4262
Investigator: W.E. Wichman		5460	182	30		4/10	15 to 30 min.	30	4257	3639	4980
Method of Dispersion: Spray (in acetone)		7363	199	37		4/10	10-15 min(3)*,45(1)	50	5417	4732	6201
		8250	165	50		6/10	15-30 min(3),[illegible](3)	84	8552	6683	10943
		10800	108	100		7/10	< 30 min (7)	99	15768	9766	25456
								SLOPE - 5.0			

* Number in parenthesis indicates number of animals

Appendix

Table A-XV. Continued

Source of/and Pertinent Information	Species	Ct mg min/cu m	Conc mg/cu m	Exposure Time min	Observation Period	Mortality Fraction	Times to Death	P	ED(P)	Lower Limit	Upper Limit
Source: As above Date: June 1957 Investigator: T.A. Ballard Method of Dissemination: Dust	Mouse	315 2150 15780 16650 53150 55320 60500 70000 [illegible]	11 143 526 1110 1772 3688 2420 2333 2853	30 15 30 15 30 15 25 30 30	2 wk	0/6 2/6 3/6 1/6 2/6 0/6 4/6 5/6 2/5	Not recorded	1 16 30 50 84 99	6 16.[illegible] 11824 108715 7316943 205256510	0 0.0 663 197 0 0	X [illegible] [illegible] [illegible] X X
									SLOPE - 0.5		
Source: As above Date: July-September 1957 Investigator and Method of Dissemination: As above	Guinea Pig	3800 4950 5900 11600 13000 14400 18000 19400 25300 27400 29640 37800 65800	127 152 197 387 433 547 607 647 843 913 988 1260 2040	30 30 30 30 30 30 30 30 30 30 30 30 30	2 wk	0/4 0/4 2/4 2/4 3/4 3/4 2/4 2/4 1/4 3/4 4/4 4/4 4/4	Not recorded	1 16 30 50 84 99	1397 4996 7833 18896 [illegible] 119779	263 2125 4297 8616 17429 20961	7412 11746 14872 [illegible] [illegible] 307309
									SLOPE - 2.4		
Source: As above Date: February 1964 Investigator: V.E. Richman Method of Dissemination: Spray (in acetone)	Guinea Pig	1390 2675 3225 8875	135 134 161 178	10 20 20 50		2/10 2/10 2/10 8/10	2 to 3 days	1 16 30 50 84 99	450 1766 2861 4900 13996 53322	52 766 1724 2604 [illegible] 2921	[illegible] [illegible] [illegible] [illegible] [illegible] 913397
									SLOPE - 2.2		
Source: As above Date: September 1963 Investigators: T.A. Ballard, J.E. Richman Method of Dissemination: As above	Guinea Pig	569 1122 2385 4019 5083 7423	Not Recorded	Not Recorded	2 wk	0/10 0/10 4/10 3/10 2/10 2/10	Not recorded	1 16 30 50 84 99	160 2589 6701 18865 196018 2465079	0.0 1845 1012 99 1 0.0	164895 3947 [illegible] [illegible] [illegible] X
									SLOPE - 1.1		
Source, Date, Investigators and Method of Dissemination: As above	Guinea Pig	1041 1178 2282	Not Recorded	Not Recorded	2 wk	5/10 5/10 6/10	Not recorded	1 16 30 50 84 99	1.2 60 298 1102 20064 977989	0.0 3 74 277 1900 1325	1586 1126 770 4369 211849 [illegible]
									SLOPE - 9.79		

Table A-XV. Continued

Source of/and Pertinent Information	Species	Ct mg min/cu m	Conc mg/cu m	Exposure Time min	Observation Period	Mortality Fraction	Time to Death	Statistical Analysis P	ED(P)	Lower Limit	Upper Limit
Source: As above	Guinea Pig	[illegible]	208	10	[illegible]	2/10	24 hr	1	53	0.1	46624
Date: September 19[illegible]		4155	203	20		4/10		16	1300	162	10636
Investigators: T.J. Ballard		4000	240	25		2/10		30	4032	2444	6650
W.B. Richman		8033	244	33		5/10		50	14249	6529	31098
Method of Dissemination: Spray		10126	260	37		4/10		84	156183	1879	13000000
(in [illegible])		12262	195	21		5/10		99	3896114	491	4027738000
									SLOPE - 0.96		
Source: C.A. Ramsey	Rat	3100	110	30		0/2		1	879	1.6	I
F.B. Bogert		4700	140	30		0/2		16	4237	219	88048
(reference 4)		9000	300	30		2/2	48(1),72 hr(1)	30	7382	1197	45941
Date: 1948		12000	400	30	14 days	1/2	12 days	50	13718	6320	29776
Method of Dissemination: Molten [illegible] solution dropped on a hot plate.		18000	600	30	12,14 days	2/4	50 hr, 14 day	84	[illegible]	[illegible]	I
		21000	700	30	12 days	1/2	10 days	99		764	I
		24000	800	30	12,15 days	2/2	18, 48 hr		SLOPE - 1.9		
		27000	900	30		2/2	18,18 hr				
		27600	920	30		2/2	12,48 hr				
		[illegible]	1010	30	12 days	1/2	4 days				
Source: [illegible] Research	Dog	9055	526	19	2 wk	0/2	-	1	5160	2916	9137
Date: 16 September 19[illegible]		14951	516	29		1/2	< 24 hrs	16	11637	4121	[illegible]
Investigator: J.T. Weimer		26996	734	34		1/2	< 24 hrs	30	15506	5139	46754
Method of Dissemination: Spray								50	21358	7272	64727
(in [illegible])								84	39200	20531	[illegible]
								99	88400	22532	346821
									SLOPE - 3.8		
Source: Research Labs, Falls Church, Virginia	Dog	[illegible]	107	15	10 days	0/2		1	15277	No answers	
Date: 1 September 19[illegible]		14400	480	30		0/2		16	16121		
Investigators:		19500	433	45		2/2	2,3 days	30	16430		
Method of Dissemination: Spray		35000	583	60		2/2	1,3 days	50	16702		
(in [illegible])		64300	433	125		2/2	1,1 day	84	17458		
								99	18434		
									SLOPE - 57.0		
Source: [illegible] Research	[illegible]	5100	Not Recorded	Not Recorded	[illegible]	0/8	Not recorded	1	5285	1274	21980
Date: May 19[illegible]		8917				1/8		[illegible]	11266	6292	20269
Investigators: J.T. Weimer		16480				2/8		30	14716	10034	[illegible]
W.T. Richman		23480				6/8		50	19827	13157	29880
Method of Dissemination: Spray								84	34895	13727	90807
(in [illegible])								99	74393	[illegible]	463958
									SLOPE - 4.1		

Appendix

Table A-XV. Continued

Source of/and Pertinent Information	Species	Ct mg min/cu m	Conc mg/cu m	Exposure Time min	Observation Period	Mortality Fraction	Times to Death	Statistical Analysis P	ED(P)	Lower Limit	Upper Limit
Source: Hazelton Laboratories	Monkey (Rhesus)	1610	107	15	30 days	0/2		1	No limits		
Date: 1 September 1963		14400	480	30		0/2		16	24266		
Investigators:		19500	483	45		0/2		30	25115		
Method of Dispersion: Spray (in acetone)		35000	583	60		2/2	11, 12 days	50	2[illegible]098		
		64200	433	125		2/2	1, 1 day	84	2[illegible]087		
								99	30939		
									SLOPE - 31.5		
Source: Aerosol Branch	Monkey (Squirrel)	5880	147	40	Not Recorded	0/6	Not recorded	1	2919	130	65960
Date: May 1964		9464	182	52		2/6		16	5930	1444	24353
Investigators: J.T. Weimer W.R. Eichman		10725	215	50		6/6		30	7616	3323	17657
Method of Dispersion: As above		12710	155	8[illegible]		4/6		50	10069	7399	13702
		23760	[illegible]57	142		5/6		84	17091	9070	37613
								99	34726	1891	XXXX
									SLOPE - 4.3		

Appendix

Table A-XVI. A Bliss Statistical Analysis of Pure DM Toxicity for the Combined Mortalities of Each Species, All Rodents, All Nonrodents, and All Species Combined
(Experiments performed from 1918 to 1964)

Species or animal grouping	Bliss statistical analysis				
	P	ED(P)	Lower limit	Upper limit	Std. err. of slope
		mg min/cu m			
Dogs	1	3,692	800	6,308	3.4
	16	9,088	4,650	12,151	
	30	12,491	8,120	15,914	
	50	17,809	13,700	23,732	
	84	34,898	25,623	73,010	
	99	85,912	49,040	397,347	
Mice	1	4	0.0	130	0.6
	16	861	0.4	3,299	
	30	5,659	382	15,555	
	50	46,244	16,617	3,801,791	
	84	2,484,742	222,979	12,252,150,000,000	
	99	515,630,850	5,084,768	--	
Rats	1	4.7	0.0	37	0.7
	16	347	77	1,008	
	30	2,307	1,067	3,664	
	50	14,045	8,473	36,383	
	84	431,659	109,391	11,149,252	
	99	42,393,054	2,867,994	27,927,439,000	
Guinea pigs	1	30	0.9	138	0.9
	16	836	222	1,567	
	30	2,690	1,381	4,123	
	50	9,906	6,420	20,093	
	84	117,363	43,998	1,089,164	
	99	3,215,971	479,828	276,097,340	
Monkeys	1	1,987	14	4,477	3.0
	16	5,498	581	8,540	
	30	7,874	2,03[illegible]	11,288	
	50	11,756	6,686	19,023	
	84	25,140	16,531	197,278	
	99	69,567	31,776	7,907,435	
All rodents (mice, rats, and guinea pigs)	1	5	0.3	24	0.7
	16	204	178	927	
	30	2,597	1,598	3,686	
	50	16,179	10,996	26,929	
	84	519,644	180,456	3,402,042	
	99	54,136,036	6,795,347	2,268,730,400	
All nonrodents	1	2,537	821	4,268	3.0
	16	7,110	4,203	9,346	
	30	10,230	7,252	12,714	
	50	15,351	12,307	19,401	
	84	33,141	24,823	58,468	
	99	92,893	54,119	300,632	
All species combined	1	10	1	37	0.7
	16	669	303	1,111	
	30	2,915	1,957	3,935	
	50	15,052	11,041	22,941	
	84	338,579	148,643	1,283,210	
	99	21,873,306	4,314,795	314,790,270	

Note: All experiments were performed between 1918 and 1964, inclusively.

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Table A-XVII. Acute Inhalation Toxicity of DM Disseminated From a 10% Acetone Solution and a Bliss Statistical Analysis of the Mortality Responses (Experiments performed in 1965)

Species	Ct	Concn	Exposure time	Mortality fraction	Times to death	Bliss statistical analysis				
						P	ED (P)	Lower limit	Upper limit	Slope
	mg min/cu m	mg/cu m	min		hr		mg min/cu m			
Monkey	40,000	296	135	6/6	28, 43, 149, 190(2),[a] 248	1	11,604	6,339	21,242	12.5
	25,085	214	117	4/6	43, 47, 57, 148, 235, 307	16	14,842	10,907	20,196	
	20,800	219	95	4/6	42, 65, 238, 286	30	16,189	13,038	20,101	
	16,720	209	80	3/6	192, 278, 350	50	17,817	15,151	20,725	
	12,555	279	45	0/6	–	84	21,414	16,740	27,445	
	5,940	297	20	0/6	–	99	27,416	16,040	46,828	
Dog	16,720	209	80	6/6	10, 16, 17, 35(3)	1	2,709	1,218	6,022	5.44
	12,555	279	45	4/6	18, 20, 42, 116	16	4,995	3,251	7,675	
	9,060	206	44	5/6	63, 86, 278, 336, 356	30	6,199	4,450	8,616	
	5,940	297	20	1/6	305	50	7,888	5,951	10,457	
	2,960	212	14	0/6	–	84	12,455	8,205	18,908	
						99	22,970	10,489	50,297	
Goat	11,600	210	198	6/6	4, 16(2), 72, 77, 113	1	1,631	990	13,316	4.41
	30,000	227	132	6/6	22(2), 71, 95, 240, 552	16	7,245	3,517	14,840	
	19,640	216	91	4/6	18, 90, 198	30	9,246	5,176	15,902	
	9,800	233	42	1/6	20(2), 239	50	12,135	8,051	18,292	
	5,062	230	22	0/5	–	84	20,327	12,010	34,401	
						99	40,556	13,986	117,603	
Swine	61,000	223	273	1/6	5.5, 20, 167	1	6,183	154	247,970	2.42
	41,600	210	198	2/6	4, 135	16	21,913	7,423	64,686	
	30,000	227	132	2/6	47(2)	30	34,245	19,928	58,847	
	19,640	216	91	1/6	42	50	56,164	16,709	190,140	
	9,900	206	48	0/6	–	84	114,930	6,141	3,420,500	
						99	513,700	1,473	–	
Rat	61,000	223	273	20/20	4, 8, 20(4), 47(5), 71, 95(2), 118(2), 124, 147(2) 168	1	12,296	8,708	17,164	11.96
	40,000	296	135	20/20	3(2), 47(2), 120(10), 190(4), 216(2)	16	15,887	13,582	18,584	
	25,085	214	117	18/20	29, 110(12), 134, 158, 211(3)	30	17,398	15,744	19,209	
	19,640	216	91	14/20	68(3), 140(3), 146, 148, 164(6)	50	19,237	17,984	20,648	
	16,720	209	80	1/20	11	84	23,298	19,644	27,614	
	12,555	279	45	1/20	21	99	30,042	21,060	43,120	
	5,940	297	20	0/20	–					
Guinea pig	16,720	209	80	16/20	11(6), 17, 35(7), 42, 66, 96	1	420	154	1,142	2.21
	12,555	279	45	19/20	19(14), 26(2), 528(2), 552	16	1,658	971	2,833	
	5,940	297	20	11/20	14(8), 21(2), 40	30	2,692	1,885	4,017	
	2,960	212	14	8/20	14, 16, 18(5), 70	50	4,623	3,191	6,301	
	1,100	220	5	1/20	230	84	12,885	8,252	20,119	
						99	50,860	20,849	121,970	
Rabbit	40,000	296	135	6/6	2, 25(5)	1	171	0.00	0.00	1.90
	14,560	100	145	6/6	2(5), 24	16	870	0.00	0.00	
	29,140	107	95	6/6	2(4), 2.5, 24	30	1,538	0.00	0.00	
	20,980	279	75	6/6	1.5, 2, 24(3), 48	50	2,983	0.00	0.00	
	11,070	246	45	6/6	1.2, 2, 24, 48	84	9,687	1,309	71,715	
	8,050	268	30	6/6	24(2), 48, 72	99	48,638	0.00	–	
	4,290	286	15	5/6	24, 72(2), 216, 240					
All rodents (rats and guinea pigs)						1	561	42	7,604	1.81
						16	3,879	911	10,175	
						30	5,609	2,733	11,512	
						50	10,951	8,397	14,288	
						84	18,349	10,269	99,164	
						99	211,000	21,093	2,150,884	
All nonrodents						1	217	4	11,719	1.19
						16	1,970	276	14,017	
						30	4,293	1,217	15,142	
						50	10,233	5,996	17,463	
						84	53,155	14,917	190,841	
						99	482,792	20,161	11,561,368	
All species combined						1	804	281	3,178	1.96
						16	3,834	2,009	7,316	
						30	6,693	4,661	9,919	
						50	12,399	10,283	14,765	
						84	19,498	13,804	64,539	
						99	188,289	55,071	643,746	

[a] Number in parentheses number of mortalities at the given times, otherwise, a single mortality occurred.

Table A-XVIII. A Bliss Statistical Analysis of Pure DM Toxicity for the Combined Mortalities of Each Species. All Rodents, All Nonrodents, and All Species Combined (Experiments performed from 1918 to 1965)

Species or animal grouping	Bliss statistical analysis				
	P	ED (P)	Lower limit	Upper limit	Std. err. of slope
		mg min/cu m			
Mice	1	4	0.0	130	0.6
	16	860	0.4	3,299	
	30	5,659	382	15,555	
	50	46,245	16,617	3,803,104	
	84	2,485,012	222,988	21,268,239,000	
Rats	1	50	9.6	138	1.0
	16	1,192	607	1,851	
	30	3,649	2,479	4,890	
	50	12,710	9,636	17,871	
	84	135,506	73,360	359,765	
	99	3,223,638	962,518	23,160,398	
Guinea pigs	1	99	23	236	1.3
	16	1,099	583	1,638	
	30	2,564	1,742	3,399	
	50	6,599	5,087	8,909	
	84	39,616	24,235	88,749	
	99	436,807	166,153	2,274,967	
Rabbits	1	173	0.0	1,420	1.9
	16	870	0.0	3,323	
	30	1,538	0.0	4,565	
	50	2,903	0.0	6,745	
	84	9,687	0.0	3,125,798	
	99	48,638	18,711	0.0	
Dogs	1	1,979	536	3,535	2.7
	16	6,052	3,306	8,212	
	30	8,900	6,060	11,463	
	50	13,945	10,857	18,249	
	84	32,130	23,200	62,325	
	99	90,261	53,580	386,501	
Monkeys	1	3,615	1,231	5,680	4.0
	16	7,811	4,556	10,081	
	30	10,252	7,092	12,649	
	50	13,886	10,984	17,235	
	84	24,685	19,429	40,165	
	99	53,340	34,699	149,876	
Goats	1	3,631	990	13,316	4.4
	16	7,245	3,537	14,840	
	30	9,246	5,376	15,902	
	50	12,135	8,051	18,292	
	84	20,327	12,010	34,401	
	99	40,556	13,986	117,603	
Swine	1	6,183	154	247,970	2.4
	16	21,913	7,423	64,686	
	30	34,245	19,928	58,847	
	50	56,184	16,799	190,149	
	84	114,930	6,141	3,420,500	
	99	513,700	1,473		
All rodents	1	33	9	77	0.9
	16	969	569	1,372	
	30	3,120	2,329	3,948	
	50	11,769	9,451	15,233	
	84	145,912	86,815	305,618	
	99	4,248,978	1,517,258	18,937,682	
All nonrodents	1	899	307	1,679	2.0
	16	4,281	2,491	5,780	
	30	7,238	5,119	9,113	
	50	13,280	10,890	16,830	
	84	41,983	31,769	65,562	
	99	196,093	110,122	528,632	
All species combined	1	57	22	113	1.0
	16	1,178	788	1,598	
	30	3,431	2,693	4,185	
	50	11,309	9,548	13,689	
	84	108,616	74,383	179,939	
	99	2,246,754	1,043,636	6,367,579	

Table A-XIX. Acute Inhalation Toxicity of DM Disseminated From an M6A1 Munition and a Bliss Statistical Analysis of These Data
30 day Observation - 1965 Experiments only

Species	Ct	Concentration	Exposure Time	Mortality Fraction	Times to Death	Statistical Analysis				
						P	ED(P)	Lower Limit	Upper Limit	Slope
	mg min/cu m	mg/cu m	min		hrs.					
Monkey	36,500	2,808	13	4/6	17 (3)*, 19	1	4,324	441	42,314	1.37
	34,900	2,685	13	6/6	18 (4), 20, 192	16	10,263	3,420	29,912	
	28,200	2,689	9	3/6	22, 23 (2)	30	13,923	7,169	27,041	
	17,600	2,514	7	4/6	24 (2)	50	19,569	14,193	26,980	
	14,400	1,800	8	3/6	43 (3)	84	37,388	15,599	89,256	
	13,900	1,986	7	0/6	-	99	88,538	11,119	-	
Dog	43,700	2,983	15	5/6	5, 22 (3), 48	1	13,351	6,417	27,776	2.12
	36,900	2,460	15	5/6	24 (5)	16	20,482	13,906	30,167	
	29,500	2,269	13	2/6	24, 31	30	23,821	17,878	31,739	
	17,600	2,514	7	1/6	41	50	28,193	24,673	32,212	
	14,300	1,565	9	0/6	-	84	38,882	21,897	94,069	
	6,200	886	7	0/6	-	99	99,529	30,599	115,812	
Goat	36,500	2,808	13	5/6	17 (2), 18, 48, 72	1	368	0.1	xx	1.32
	34,900	2,685	13	6/6	18 (5), 138	16	2,196	16	xx	
	25,600	2,327	11	4/6	3, 4 (2), 50	30	4,025	112	xx	
	14,400	1,800	8	4/6	44 (2), 288, 360	50	8,016	945	69,016	
	12,200	2,033	6	4/6	44 (3), 288	84	38,228	10,063	90,804	
						99	xx	1,664	xx	
Swine	68,700	2,908	25	5/6	16 (2), 21, 40, 168	1	2,746	.0	8,047,813,100	0.94
	45,700	2,688	17	4/6	17 (4)	16	12,151	35.1	4,206,301	
	39,000	2,435	16	1/6	48	30	20,540	1,405	300,255	
	14,900	2,129	7	3/6	24 (2), 42	50	36,011	12,208	111,530	
	13,900	1,986	7	0/6	-	84	111,116	49	255,995,870	
						99	495,520	0.0	9,640,477,700,000	
Rabbit	45,700	2,688	17	4/6	17 (4)	1	2,292	0.0	4,922,860,000	0.94
	39,000	2,400	15	5/6	3, 24 (4)	16	11,974	68.4	2,094,405	
	39,000	2,435	16	4/6	48, 65, 165 (2)	30	21,464	3443.1	133,812	
	34,900	2,653	13	1/6	18	50	41,129	7,645.4	221,577	
	29,500	2,269	13	0/6	-	84	141,468	23.5	851,040,070	
	18,600	2,457	7	4/6	432 (2), 456 (2)	99	739,116	0.0	49,695,089,000,000	
Rat	88,000	2,588	34	14/20	1 (6), 2(4),24(3),48	1	16,409	13,496	19,651	0.64
	50,000	2,666	19	15/20	1 (4), 2(5),24(5),48	16	36,674	34,151	39,382	
	49,500	2,574	27	15/20	4 (5),24(9),48	30	38,707	47,006	50,470	
	55,400	2,966	27	2/20	2, 48	50	66,896	64,033	69,804	
	52,100	2,717	19	1/20	96	84	121,892	105,984	xx	
	36,500	2,808	13	0/20	-	99	xx	xx	xx	
	34,900	2,685	13	5/20	259 (5)					
	17,600	2,514	7	1/20	72					
	14,300	1,589	9	1/20	268					

*Number in parenthesis indicates number of animals; otherwise one animal only died at time indicated.

Table A-XIX. Continued

Species	Ct	Concentration	Exposure Time	Mortality Fraction	Time to Death	Statistical Analysis: P	ED(P)	Lower Limit	Upper Limit	Slope
	mg min/cu m	mg/cu m	min		hrs					
Guinea Pig	17,600	2,514	7	18/20	3 (6), 24 (12)	1	2,542	1,705	3,780	0.70
	14,400	1,800	8	19/20	2 (4), 43 (15)	16	6,853	5,388	7,492	
	14,300	1,586	9	5/20	20 (4), 264 (1)	30	8,778	8,066	9,553	
	13,900	1,986	7	4/20	21 (2), 96 (2)	50	12,591	12,155	13,042	
	6,200	886	7	7/20	< 1 (3), 24 (2), 720 (2)	84	24,946	20,552	30,218	
	5,540	1,385	4	0/20	-	99	62,350	40,619	95,704	
All Rodents						1	384	0.6	251,830	0.222
						16	8,362	1,266	55,248	
						30	24,798	16,115	38,160	
						50	83,380	6,125	431,143	
						84	851,395	5,243	131,832,220	
						99	18,083,876	1,128	289,951,250,000	
All Non-Rodents						1	1,605	1,505	1,712	0.459
						16	7,635	7,418	7,899	
						30	13,237	13,015	13,462	
						50	24,462	24,277	24,648	
						84	78,332	76,222	80,508	
						99	xx	xx	xx	
All Species Combined						1	176	1.8	17,512	0.184
						16	4,144	760	22,595	
						30	12,634	6,266	25,476	
						50	43,808	24,549	78,178	
						84	463,066	31,124	6,889,632	
						99	10,890,876	39,867	2,975,150,600	

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Table A-XX. Acute Inhalation Toxicity of DM Disseminated From Commercial Munitions and a Bliss Statistical Analysis of These Data 30-Day Observation (1965 Experiments only)

Species	Ct	Concn	Exposure time	Mortality fraction	Times to death	Bliss statistical analysis				
						P	ED(P)	Lower limit	Upper limit	
	mg min/cu m	mg/cu m	min		hr		mg min/cu m			
Monkey	29,000	1,222	9	6/6	1(2), * 5(2), 24, 28	1	8,131	1,097	60,252	5.2
	26,270	3,753	7	1/6	17	16	14,678	6,838	31,509	
	18,200	3,033	6	3/6	17(2), 332	30	18,080	12,460	26,235	
	14,600	2,433	6	1/6	42	50	22,814	16,297	31,916	
	10,600	2,600	4	0/6	–	84	35,459	10,730	117,182	
						99	66,007	5,534	739,593	
Dog	51,600	3,686	14	6/6	<1, 17(4), 41	1	9,699	2,881	32,659	5.0
	42,160	4,216	10	5/6	18(3), 96, 163	16	17,952	9,763	33,009	
	29,000	3,222	9	2/6	48, 78	30	23,309	14,686	33,889	
	26,270	3,753	7	2/6	48, 72	50	28,438	21,623	37,376	
	14,200	3,560	4	1/6	384	84	45,819	27,875	72,708	
						99	83,322	28,597	242,771	
Goat	97,800	3,622	27	6/6	<1(4), 16(2)	1	1,072	69	16,611	2.2
	77,500	3,875	20	6/6	16(5), 138	16	4,216	867	20,497	
	60,000	5,000	12	5/6	22, 240(2), 456, 648	30	6,837	2,084	22,433	
	50,550	3,611	14	6/6	17(2), 96, 144, 164, 264	50	11,723	5,135	25,763	
	36,135	4,015	9	5/6	48(2), 600, 624(2)	84	12,595	18,155	58,520	
	22,400	3,200	7	4/6	18, 316, 456, 720	99	128,200	24,528	619,565	
	13,160	3,285	4	4/6	18, 560, 672, 552					
	8,500	2,125	4	2/6	600, 672					
Swine	60,000	5,000	12	6/6	22(6)	1	20,874	7,605	58,837	9.9
	43,680	4,360	10	4/6	5(2), 22(2)	16	28,467	16,713	48,487	
	36,135	4,015	9	4/6	20(3), 672	30	31,761	22,016	45,821	
	22,400	3,200	7	0/6	–	50	35,888	28,854	44,637	
	13,160	3,285	4	0/6	–	84	45,345	32,265	63,660	
						99	61,704	27,084	140,564	
Rabbit	97,800	3,622	27	12/12	16(12)	1	16,894	8,279	34,475	5.2
	77,500	3,875	20	12/12	17(12)	16	30,333	21,909	42,777	
	60,700	4,669	13	2/6	18(2)	30	37,294	29,534	47,092	
	51,600	3,686	14	2/6	17, 41	50	46,959	39,613	55,665	
	42,160	4,216	10	2/6	18, 96	84	72,698	51,944	101,706	
	36,600	4,575	8	1/6	216	99	130,527	66,561	263,975	
	29,000	3,222	9	4/6	2(2), 24(2)					
	26,270	3,753	7	0/6	–					
	25,725	3,675	7	0/6	–					
	14,600	2,433	6	0/6	–					
	14,200	3,560	4	0/6	–					
Guinea pig	77,500	3,875	20	19/40	1(19), 17(20)	1	9,361	6,325	20,261	4.4
	51,600	3,686	14	17/20	<1, 17(16)	16	18,195	12,626	26,225	
	50,550	3,611	14	20/20	>1(9), 17(11)	30	23,005	18,282	28,950	
	42,160	4,216	10	19/20	2(2), 18(13)	50	29,888	26,613	33,544	
	29,000	3,222	9	17/20	2(6), 4(6), 24(4), 597	84	49,096	36,633	65,814	
	26,270	3,753	7	0/20	–	99	99,432	67,572	191,419	
	25,725	3,675	7	0/20	–					
	14,600	2,433	6	1/20	18					
	14,200	3,560	4	4/40	18, 42, 402(2), 600, 609					
	8,500	2,125	4	0/20	–					
Rat	97,800	3,622	27	39/40	16(38), 32(1)	1	11,520	9,768	35,578	1.8
	77,500	3,875	20	39/40	17(32), 34(2)	16	26,804	19,770	63,514	
	51,600	3,686	14	18/20	17(7), 604(2)	30	34,958	25,935	67,120	
	50,550	3,611	14	2/20	17(2)	50	46,217	42,489	54,718	
	42,160	4,216	10	1/20	19	84	80,730	56,188	140,117	
	29,000	3,222	9	12/20	24(12)	99	200,881	68,819	583,099	
	26,270	3,753	7	0/20	–					
	14,600	2,433	6	3/20	18(2), 42					
	14,200	3,560	4	0/20	–					

* Number in parenthesis indicates number of mortalities at the given time, otherwise, a single mortality occurred

Table A-XX. (Continued)

Species	Ct	Concn	Exposure time	Mortality fraction	Times to death	Bliss statistical analysis				
						P	ED(P)	Lower limit	Upper limit	Std. err. of slope
	mg min/cu m	mg/cu m	min		hr		mg min/cu m			
All rodents						1	8,665	4,030	18,628	3.6
						16	20,192	14,243	28,627	
						30	27,220	22,095	33,532	
						50	37,980	34,593	41,699	
						84	71,439	52,477	90,401	
All nonrodents						1	4,988	2,172	11,453	3.0
						16	13,948	9,411	20,673	
						30	30,053	15,576	25,816	
						50	30,063	25,848	34,965	
						84	64,794	45,804	91,656	
						99	181,199	82,966	395,738	
All species combined						1	5,823	111	306,223	3.0
						16	16,714	2,792	93,705	
						30	23,197	8,711	61,770	
						50	34,683	30,245	39,773	
						84	74,374	15,886	348,206	
						99	206,579	4,862	8,776,949	

Table A-XXI. Subacute Inhalation Toxicity of DM Disseminated From Commercial Munition in Guinea Pigs, Dogs, and Monkeys
(Exposures daily for 10 days)

Day	Group I daily Ct	Cumulative Ct	Cumulative deaths			Daily Ct	Cumulative Ct	Cumulative deaths		
			Guinea pig	Dog	Monkey			Guinea pig	Dog	Monkey
	mg min/cu m					mg min/cu m				
1	9,740	–	0/20	0/8	0/8	16,620	–	1/20	0/8	0/8
2	12,020	21,760	–	–	–	16,020	32,640	–	1/8	1/8
3	11,060	32,820	–	–	–	17,560	50,200	–	–	2/8
4	11,000	43,820	–	–	–	15,920	66,120	–	–	–
5	12,920	56,740	–	–	–	16,920	83,040	–	2/8	–
6	11,620	68,360	–	–	–	17,360	100,400	–	–	3/8
7	11,750	80,110	–	–	–	14,540	114,940	–	–	–
8	9,940	90,050	–	–	–	19,020	133,960	3/20	–	–
9	13,720	103,770	1/20	–	–	21,660	155,620	4/20	–	–
10	12,320	116,090	2/20	0/8	0/8	17,400	173,020	4/20	2/8	3/8
11			2/20	–	2/8			12/20	–	4/8
12			–	–	3/8			18/20	–	6/8
13			–	–	4/8			–	–	–
16			–	1/8	–			–	–	–
17			–	–	–			–	–	8/8
20			3/20	–	–			–	–	–
24			–	–	5/8			–	–	–
30			3/20	1/8	5/8			18/20	2/8	8/8

Note: The acute lethal Ct's for DM disseminated from the Commercial grenade are:

Monkey		Dog		Guinea pig	
P	Ct mg min/cu m	P	Ct mg min/cu m	P	Ct mg min/cu m
1	8,131	1	9,699	1	9,361
16	14,678	16	17,952	16	18,195
30	18,080	30	23,309	30	23,005
50	22,814	50	28,428	50	29,888
84	35,459	84	45,019	84	45,096
99	64,007	99	83,322	99	95,432

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